(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 695 569 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.02.1996 Bulletin 1996/06

(51) Int. Cl.[6]: A63H 18/16, G01P 3/68

(21) Application number: 95112039.3

(22) Date of filing: 31.07.1995

(84) Designated Contracting States:
DE GB

(30) Priority: 01.08.1994 JP 180289/94

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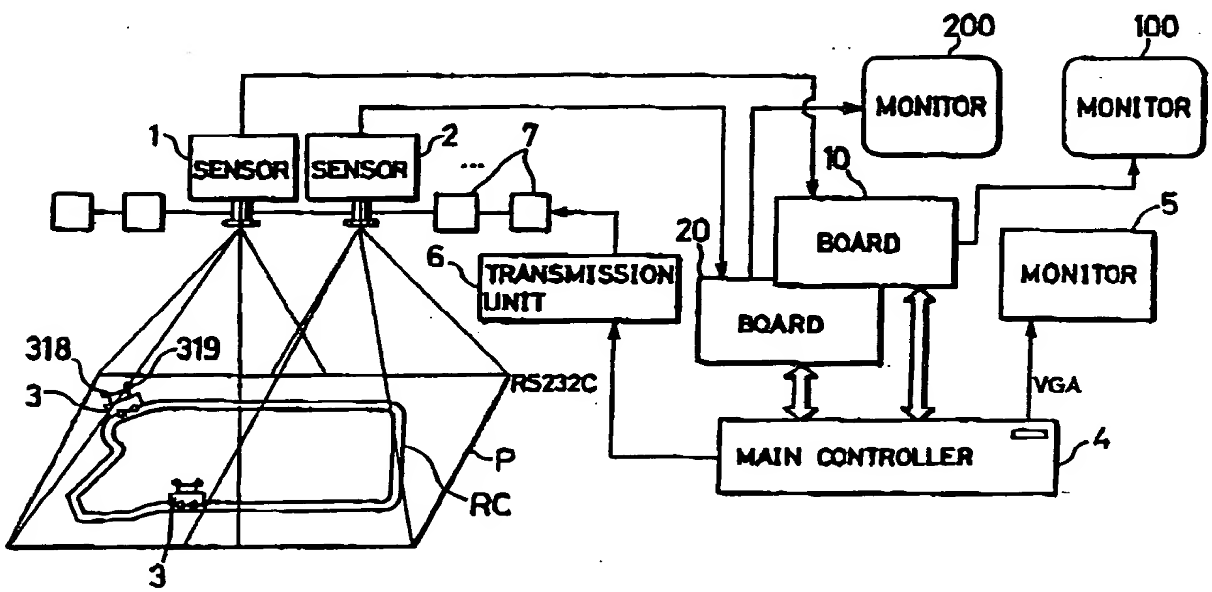
(54) A system for detecting a position of a movable object without contact

(57) A position detecting system for detecting a position of a movable object having a light emitter without contact, the system includes: a first light sensor which has a first view area and receives light from the light emitter of the movable object in the first view area to produce image data, and a second light sensor which has a second view area and receives light from the light emitter of the movable object in the second view area to produce image data, a combination of the first and second view areas covering a space in which the movable object moves, and the first and second view areas overlapping each other; and a processor which calculates a position of the movable object based on image data produced by the first and second light sensors.

FIG. 1



The designator may be made to designate an address block in the local address system of the first memory when a portion of an address block having been designated in the local address system of the second memory is beyond the border addresses of the second memory, and to designate an address block in the local address system of the second memory when a portion of an address block having been designated in the local address system of the first memory is beyond the border addresses of the first memory.

It may be preferable that each of the first and second light sensors includes an area sensor provided with photoelectric conversion elements arranged in a matrix; and the position calculating device includes: a counting portion which counts the number of photoelectric conversion elements which have received light from the light emitter of the movable object based on the image data read by the reader; a coordinate value accumulating portion which accumulates coordinate values of the photoelectric conversion elements counted by the counting portion; and a calculating portion which calculates a position of the movable object based on the counted number and the accumulated coordinate values.

The designator may be constructed by a moved amount calculating portion which calculates a moved amount of the movable object based on the calculated position of the movable object; and a designating portion which designates an address block based on a previously calculated position of the movable object and the calculated moved amount.

Each of the first and second light sensors may be preferably provided with a lens for focusing a light image on a surface of the light sensor.

It may be preferable that the light emitter is operable to emit light lying outside a frequency band for visible radiations; and each of the first and second light sensors is operable to receive only light lying in the same frequency band of light emitted by the light emitter.

With a position detecting system of the present invention, there is provided at least two light sensors. The view area of one light sensor overlaps the view area of another light sensor. Accordingly, an object moving in a large space can be reliably detected by two or more light sensors. Also, the detection space can be widened by increasing the number of light sensors.

The position calculator calculates a position of the movable object in the terms of a general address system unifying respective local address systems of the first and second memories. Addresses in the respective local address systems are converted to those in the general address system based on the border addresses by the address converting device. Accordingly, a movement of the object over the first and second view areas can be smoothly traced.

Also, the position calculator is provided with the designator to designate an address block in the local address system of either the first memory or the second memory. A position of the movable object is calculated based on image data within the designated address block. Accordingly, the position calculation can be performed at a higher speed.

The designation of an address block is changed from the first memory to the second memory, and vice versa based on the border addresses of each memory. An address block can be properly set with respect to a movement of the movable object.

The counting portion counts the number of photoelectric conversion elements which have received light from the light emitter based on the contents stored in the designated block. On the other hand, the coordinate value accumulating portion accumulates coordinate values of the photoelectric conversion elements counted by the counting portion. A position of the movable body is calculated based on the obtained count value and the accumulated coordinate value, which will consequently provide more accurate position at a higher speed.

An address block is set based on the previously calculated position and moved amount. There is provided the corrector which corrects the calculation result which has the influence of a distortion of the lens. Accordingly, more accurate position calculation can be attained.

The light emitter is allowed to emit light lying outside the band for the visible radiations, and the light sensor receives only the light lying the same frequency band of the light emitted by the emitter device. This will increase the preciseness in the position calculation.

These and other objects, features and advantages of the present invention will become more apparent upon a reading of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view showing an overall construction of a game machine embodying the present invention, together with a block diagram of the game machine;

Fig. 2 is a perspective view showing a relationship between two areas viewed by two image pick-up devices or TV cameras;

Fig. 3 is a block diagram showing a horizontal arrangement of main parts of a car;

Fig. 4 is a schematic diagram showing a construction of electric boards provided with an electric circuit for detecting the position of the car;

Fig. 5 is a block diagram showing a portion of a processor which detects the position of the car;

Fig. 6 is a detailed circuit diagram of a binary processing circuit;

Fig. 7 is a timing chart showing an operation of the circuit shown in Fig. 6;

1/60 second (one field) or in a scanning cycle of 1/30 second (one frame). Electrical signals converted to have level corresponding to amounts of light received by the respective photoelectric conversion elements are output from the TV camera 1 (2). The TV camera 1 (2) used in this embodiment has an infrared transmitter filter disposed on its light receiving surface so that it receives only the infrared radiations in a specified frequency band. This prevents an erroneous operation caused by external light. In this embodiment, the upper surface of the base P is divided into two areas and the two TV cameras 1, 2 pick up images in their corresponding areas. However, the upper surface of the base P may be divided into a plurality of areas more than two and the respective TV cameras may pick up images in their corresponding areas. In this way, the resolution of the picked up images, i.e., the position detection accuracy can be improved, while realizing the race track RC in an expanded area.

The boards 10, 20 are connected to the TV cameras 1 and 2, respectively. The boards 10, 20 each are internally provided with the electrical circuit for detecting the car 3, which will be described later with reference to Figs. 4 and 5.

The monitors 100, 200 are not needed during the game, but are adapted to display auxiliary members for position adjustment, i.e., LED1, LED2 and LED3, which are used to adjust the direction of the TV cameras 1 and 2 in the production and maintenance, or to display a detecting state of the car 3 for confirmation.

The transmission LEDs 7 are light emitting devices for emitting, for example, infrared radiations. Similar to the TV camera 1 (2), the LEDs 7 are disposed at specified height from the base P with the light emitting portions faced downward. The infrared signals from the LEDs 7 are directed at the car 3 running on the race track RC and propagates while spreading at a specified angle. Only one transmission LED 7 may be disposed in the center position. In order to make the signal transmission reliable, two LEDs may be disposed to cover the respective areas defined by dividing the surface of the base P into two parts. In this embodiment, four LEDs are disposed serially to cover the respective areas defined by dividing the surface of the base P into four parts. With a plurality of LEDs 7, the transmission unit 6 transmits a synchronized optical pulse signal to the respective LEDs 7 connected in serial therewith. Thus, even if the areas covered by the respective LEDs 7 partially overlap, no interference occurs, with the result that the occurrence of the erroneous operation can be prevented. In place of the connecting method shown in Fig. 1, the LEDs 7 may be connected in parallel so as to suppress the influence of impedance more effectively, or may be serially connected via drivers (using shield wires) so as to suppress the influence of impedance and to prevent the noise generation. The connecting method shown in Fig. 1 is advantageous as compared with the other connecting methods in that the wiring construction is simplified.

Fig. 3 is a block diagram showing the construction of the car 3.

The car 3 has an unillustrated body, which has a so-called three-point support structure. In other words, wheels 311, 312 are rotatably mounted at the opposite lateral sides of the front side of the car body, and an unillustrated ball (ball caster) is disposed in the center of the rear (or front) side of the car body. This ball is fitted in a partially spherical hole which is formed on the bottom surface of the car body so as to volumetrically accommodate at least the half of the ball. The ball is rollable by 360 degrees. By adopting the three-point support structure, the slip of the car body can be effectively simulated. In place of the ball, rotatable wheels may be mounted at the opposite lateral sides.

The car 3 includes motors 313 and 314 for driving the wheels 311 and 312 formed of resin or like material, respectively. DC motors are used as the motors 313 and 314. The speed of the car 3 is duty-controlled and, if necessary, the car 3 is caused to run backward (by inverting the polarity of a supply current). Alternatively, pulse motors capable of controlling the speed using a pulse frequency may be used. A plurality of reduction gears are mounted between rotatable shafts of the motors 313 and 314 and those of the wheels 311 and 312 so that a specified speed range is obtainable. Further, rotating speed detectors 315 and 316 for detecting the rotating speed of the motors 313 and 314, respectively, are provided so as to feedback-control the speed of the car 3. The detectors 315, 316 include rotating plates 315a, 316a formed with perforations at specified intervals in their circumferential direction and which are rotatably mounted on the rotatable shafts of the motors 313 and 314, and photointerrupters 315b, 316b disposed to hold the rotating plates 315a, 316a therebetween to detect the perforations formed in the plates 315a, 316a, respectively.

Indicated at 317 is a one-chip microcomputer as a controller for the car 3. The microcomputer 317 analyzes the signals transmitted from the LEDs 7 of the machine main body to generate a running control signal for the car 3, and causes front and rear LEDs 318 and 319 to emit infrared radiations. Its operation program is stored in a ROM 320. Indicated at 313a and 314a are amplifiers for amplifying the speed control signals output from the microcomputer 317 and sending the amplified signals to the motors 313 and 314, respectively.

As shown in Figs. 1 and 3, the front LED 318 is disposed in the center of the front part of the car 3, whereas the rear LED 319 is disposed in the center of the rear part of the car 3. These LEDs 318 and 319 face straight above. The frequency band of the infrared radiations emitted from the LEDs 318 and 319 coincides with the transmission frequency band of the infrared transmitter filter disposed on the front surface of the TV cameras 1 and 2. The LEDs 318 and 319 are constructed such that the light emitted therefrom propagate while spreading at a wide angle. Thus, the image of the car 3 in any arbitrary position on the base P can be picked up by the TV cameras 1 and 2.

Referring back to Fig. 3, indicated at 321 is an infrared receiving unit which includes a photodiode or like device for receiving the optical pulse signals transmitted from the LEDs 7. The unit 321 is disposed, for example, in the middle of the top of the car 3 with faced upward. This photodiode is, for example, exposed so that it can receive the light from the wide range of directions. Indicated at 322 is a storage battery including a Ni-Cd battery capable of storing and releasing

Fig. 6 is a detailed circuit diagram of the binary processing circuit 19, and Fig. 7 is a timing chart showing its operation. In Fig. 6, indicated at 191 is an amplifier for amplifying an NTSC signal including image data from the TV camera 1 (2), and the thus amplified signal is converted into a signal having a specified voltage level by a circuit 192 including an AC coupling circuit. The thus converted signal is output to a noninverting input terminal of a comparator 193 including an operational amplifier. A D/A converter 194 is a digital-to-analog converting circuit and is adapted to convert a threshold data of, e.g., 8 bits input from the microcomputer 40 into an analog signal and to output the resultant signal to the inverting input terminal of the comparator 193. The comparator 193 outputs a signal of high level if the level of the NTSC signal is a threshold level or higher, and the output data thereof is sent to a serial parallel converter 195. The serial parallel converter 195 converts the received binary data into a data consisting of 8 bits in synchronization with a sampling clock and outputs the converted data to a latch circuit 196. The latch circuit 196 latches and outputs this signal to the frame memory unit 11. The binary parallel data is written in the frame memory unit 11 at a timing when a write pulse (bar WR) output during the reading of the data for 8 pixels is sent.

Accordingly, as shown in Fig. 7, the data is written such that the pixels of the TV camera 1 correspond to the addresses of the frame memory unit 11: the data from the first pixel (data of ADD0) is written in an address ADD0, a data of ADD1 in an address ADD1, a data of ADD2 in an address ADD2, and so on. The employment of the D/A converter 194 in the binary processing circuit 19 to compare the levels in an analog manner enables the use of a threshold data consisting of a larger number of bits as compared with a conventional case where the digital data are compared for the NTSC signal in the high frequency band. Thus, the resolution of the level comparison can be advantageously enhanced. It will be appreciated that the invention does not deny the employment of the conventional circuit construction for comparing the digital data, and that either one of the constructions is employed in view of a required resolution accuracy.

Figs. 8A to 8C are diagrams showing the operation of the data reading circuit 18, Fig. 8A showing a base located within a view of a TV camera, Fig. 8B showing storage contents of a frame memory in the state shown in Fig. 8A, and Fig. 8C enlargedly showing a trace block BL1.

In Fig. 8A, one car 3 is located on the base P, and the front and rear LEDs 318 and 319 are on. In Fig. 8B, LED pixel data D1 and D2 corresponding to the front and rear LEDs 318 and 319 are stored at high level. BL1 and BL2 denote trace blocks.

In Fig. 8C, checkers within the trace block BL1 represent the pixels of the TV camera 1, i.e., the respective addresses of the frame memory unit 11. In this embodiment, there is adopted a square trace block having a side which is at least twice as long as a distance the car 3 moves in one field cycle (half the frame cycle). In this way, the movement of the car in 360° directions can be more securely traced. The upper left end (Hs, Vs) of the trace block BL1 is a starting address of the trace block BL1, which is set by the start setting circuit 141. The H-, V-counter 142 designates the addresses in a row direction (a direction indicated by an arrow in Fig. 8C) from the starting address (Hs, Vs), i.e., (Hs+1, Vs), ..., (Hs+d, Vs). Upon the completion of one row, the address proceeds to the next row. The address designation ends at an end address (Hs+d, Vs+d). In this way, the trace block BL1 of dxd (referred to as a trace block size BS hereinafter) is designated.

By selecting the shape of the focus lens disposed on the sensing surface of the TV camera 1 and the shape and luminance of the front and rear LEDs 318 and 319, the LED data D1 may be stored over a plurality of addresses (as in a hatched portion in Fig. 8C). By obtaining a plurality of dots, the LED data can be made distinguishable from other noises.

The integration is described with reference to Figs. 5 and 8C. Upon the address designation of the trace block BL1 from the read address generator 14, stored contents of the addresses are successively read from the frame memory 111 (or 112). Simultaneously, the read addresses are sent to the adding circuit 181.

Each time one dot (high level data) as the LED data D1 is read from the frame memory 111, the count value of the dot counter 183 is incremented and the read dot is sent to the latch circuit 182. Only when receiving the dot data, the latch circuit 182 latches the address value output from the adding circuit 181 and sends the address value back to the adding circuit 181. In this way, each time the dot data is output from the frame memory 111, the address value for storing this dot data is output to the adding circuit 181 and integrated therein.

As a result, the number of dots existing in the trace block BL1 and the integration value of the addresses for these dots are obtained in the dot counter 183 and the latch circuit 182, respectively. Upon the completion of the address designation of the trace block BL1, the microcomputer 40 reads the data obtained in the latch circuit 182 and the dot counter 183, and judges based on the dot number whether the data is a LED data or a noise. A center address (Hc, Vc) of the dots is calculated by dividing the integration value by the dot number. The center address is assumed to be the position of the front LED 318. In accordance with this position data, the trace block is set and the running control signal for the car is generated.

The judgment as to whether the data is a LED data or a noise may be made as follows. A threshold dot number is set, and the data having the dot number which is not smaller than the threshold value is judged to be the LED data.

Further, the center address may be calculated by the hardware, and the H-, V-coordinates calculation results may be sent to the microcomputer 40. Instead of the use of absolute coordinates in calculating the integration value of the coordinates, relative coordinates from reference coordinates may be used. In this case, target coordinates are obtained

results obtained by Equations 1 and 2.

EQUATION 1:

$$h10=\frac{(h11^2+v11^2)(v12-v13)+(h12^2+v12^2)(v13-v11)+(h13^2+v13^2)(v11-v12)}{2\cdot h11(v12-v13)+2\cdot h12(v13-v11)+2\cdot h13(v11-v12)}$$

$$v10=\frac{(h11^2+v11^2)(h13-h12)+(h12^2+v12^2)(h11-h13)+(h13^2+v13^2)(h12-h11)}{2\cdot h11(v12-v13)+2\cdot h12(v13-v11)+2\cdot h13(v11-v12)}$$

$$r10=\sqrt{\{(h10-h11)^2+(v10-v11)^2\}}$$

EQUATION 2:

$$h20=\frac{(h21^2+v21^2)(v22-v23)+(h22^2+v22^2)(v23-v21)+(h23^2+v23^2)(v21-v22)}{2\cdot h21(v22-v23)+2\cdot h22(v23-v21)+2\cdot h23(v21-v22)}$$

$$v20=\frac{(h21^2+v21^2)(h23-h22)+(h22^2+v22^2)(h21-h23)+(h23^2+v23^2)(h22-h21)}{2\cdot h21(v22-v23)+2\cdot h22(v23-v21)+2\cdot h23(v21-v22)}$$

$$r20=\sqrt{\{(h20-h21)^2+(v20-v21)^2\}}$$

In this way, the trace block BL can be properly set irrespective of the detected position of the car 3, thereby enabling secure trace of the car 3.

Fig. 14 is a flowchart showing a measurement of the position of the TV cameras 1 and 2.

The TV cameras 1 and 2 are positioned to pick up images of the LED1, LED2, and LED3 which are disposed at the predetermined positions of the base P. The microcomputer 40 first renders the TV camera 1 pick up images of the LED1, LED2, and LED3 and then write their respective image data in the frame memory unit 11 (Step S2). The microcomputer 40 calculates addresses (h11, v11), (h12, v12), and (h13, v13) of images of the LED1, LED2, and LED3 by scanning the frame memory unit 11 (Step S4). Specifically, the address calculation is executed as follows: the frame memory unit 11 is scanned; the continuity of dots (high level data) is detected using a known method; the number of dots in a detected continuity region is counted; and a center position of the region is calculated. This calculation is similar to an initial position recognition which will be described later.

Similarly, the microcomputer 40 renders the TV camera 2 pick up images of the LED1, LED2, and LED3 and then write their respective image data in the frame memory unit 21 (Step S6). The microcomputer 40 calculates addresses (h21, v21), (h22, v22), and (h23, v23) of images of the LED1, LED2, and LED3 by scanning the frame memory unit 21 (Step S8).

Subsequently, a segment connecting the point (h11, v11) and the point (h21, v21), a segment connecting the point (h12, v12) and the point (h22, v22), and a segment connecting the point (13, v13) and the point (h23, v23) are displayed on the game monitor 5 (Step S10). It is judged whether v11 = v21, v12 = v22, v13 = v23 (Step S12). If it is judged that v11 = v21, v12 = v22, and v13 = v23 (YES in Step S12), a distance d between the addresses (H12, V12) and (H22, V22) of the images of the LED2 is calculated as: $d = 512 - v12 - v22$, and the calculated distance d is displayed (Step S14).

In Step S16, it is judged whether a break-off key is turned on (Step S16). The break-off key is provided in the operation panel. This judgment is performed because there is the possibility that an operator requests break-off of this flow to adjust the position of the TV cameras 1 and 2 after obtaining the results of Steps S12 and S14, i.e., when it is judged that the condition of v11 = v21, v12 = v22, v13 = v23 cannot be attained, or when it is found that the calculated distance d is not within the predetermined value. As mentioned above, the conditions of v11 = v21, v12 = v22, v13 = v23 and BS ≤ min(D(v)) are necessary for the address unification. If it is judged that the break-off is requested (YES in Step S16), this routine ends.

It may be appreciated that the operations of Steps S2 to S14 is repeated after the adjustment of the TV cameras 1 and 2 is completed and the break-off key is turned on again.

If it is judged that v11 = v21, v12 = v22, and v13 = v23 (YES in Step S12), and it is found that the distance d is within the predetermined value, and the break-off key is not turned on (NO in Step S16), the value h10, h20, v10, v20, r10, and r20 are calculated based on Equations 1 and 2 (Step S18). Thus calculated r10, r20, v10, and (h10 - h20) are stored in the system parameter file (Step S20), and this routine ends.

Figs. 15 and 16 are a main flowchart showing operations of the game machine provided with the system for detecting the position of the movable object in a non-contact state. In this game machine, e.g., 8 cars are used and identification numbers ID No.i (i=0 to 7) are given in advance to the respective cars 3 by setting dip switches provided therein.

This flowchart starts after the specified operation, e.g., insertion of a medal, or input of a predicted ranking is detected and the race development is set. First, the entire system is initialized, and the communication ports of the microcomputer 40 and the main controller 4 are initialized (Steps S30 and S32). The trace block size BS is set (Step S34), and the distance D(v) is calculated (Step S36). The calculation of the distance D(v) will be described later.

Command signals are generated to turn off the front and rear LEDs 318 and 319 of all the cars 3, and are sent to all the cars 3 via the transmission LEDs 7 (Step S38).

A count value i of the counter is set to 0 (Step S40), and a command signal is generated to turn on the front LED 318 of the car of ID No.0, and is transmitted to this car via the transmission LEDs 7 (Step S42). The microcomputer 317 of the car of ID No.0 recognizes that the transmission command is directed to it, and turns only the front LED 318 on. On the other hand, after waiting for a time which is required for the luminance of front LED 318 to reach a specified level e.g., for a time corresponding to 2 frame cycles following the transmission of the command signal (Step S44), the microcomputer 40 calculates the center of gravity position to recognize an initial position of the front LED 318 of the car of ID No.0 (Step S46). This center of gravity position calculation is described in detail later. The obtained center of gravity data (Hc, Vc) is stored in the form of FH[i], FV[i] (F denotes forward) in a RAM or the like as a buffer (Step S48).

Upon the completion of the storage of the center of gravity data, a command signal is generated to turn on the rear LED 319 of the car of ID No.0, and is transmitted to this car via the transmission LEDs 7 (Step S50). The microcomputer 317 of the car of ID No.0 recognizes that the transmission command is directed to it, and turns only the rear LED 319 on (in other words, the microcomputer 317 of the car of ID No.0 turns the front LED 318 off). On the other hand, after waiting for 2 frame cycles following the transmission of the command signal (Step S52), the microcomputer 40 calculates the center of gravity to recognize an initial position of the rear LED 319 of the car of ID No.0 (Step S54). The obtained center of gravity data (Hc, Vc) is stored in the form of BH[i], BV[i] (B denotes back) in a RAM or the like (Step S56). Upon the completion of the storage of the center of gravity data of the front and rear LEDs 318 and 319, command signals

The above calculation result and the contents of the board identification flag BDF are stored in the buffer (Step S162). The noise level at this stage is stored as a system parameter (Step S164), and this subroutine returns.

In Step S130, on the other hand, if the label number is 1 (YES in Step S130), the center of gravity coordinates Hc, Vc are calculated assuming that one effective label is the front LED 318 (or the rear LED 319) (Step S152), and the calculation result and the contents of the board identification flag BDF are stored in the buffer (Step S162). The noise level at this stage is stored as a system parameter (Step S164), and this subroutine returns.

Fig. 16 is a flowchart showing the operations carried out in response to Interrupts I and II, particularly after the interrupt is enabled in Step S68.

The Interrupt I is described with reference to Fig. 20. The Interrupt I is started in response to an interrupt signal generated each time the reading of the image data in the frame memory units 11 and 21 in the boards 10 and 20 is completed. First, the frame memory unit 11 in the board 10 is switched to the frame memory 111 (or 112) in which the image data writing is completed (Step S180), and the frame memory unit 21 in the board 20 is switched to the frame memory 211 (or 212) in which the image data writing is completed (S182). Subsequently, the identification number ID No.i is set to 0 (Step S184), and the front and rear flag FBFLG is set to 0, i.e., the flag is set to the front LED 318 (Step S186).

Subsequently, the start address (Hs, Vs) of the trace block labeled in correspondence with the front LED 318 of the car of ID No. 0 is set (Step S188). In other words,

$$Hs = FH[i] - (BS/2) + AFH[i]$$

$$Vs = FV[i] - (BS/4) + AFV[i]$$

The correction amounts AFH[i] and AFV[i] are given by implementing the flowchart of Interrupt II.

As shown in Fig. 24, a quotient is set at 4 in the address Vs in view of the fact that there is 1/2 scanning line although the image stored in the frame memory is read as a binary data by the frame. In this way, a square trace block can be obtained.

Subsequently, it is judged based on the board identification flag BDF whether the front LED 318 of the car of the ID No.0 is detected by the boards 10 or by the board 20 (Step S190). If the board identification flag BDF is "0" (YES in Step S190), it is judged that the front LED 318 of the car of the ID NO.0 is detected by the board 10, and the start address (Hs, Vs) set at Step S188 is output to the start setting circuit 141 of the board 10 (Step S192).

On the other hand, if the board identification flag BDF is "1" (NO in Step S190), it is judged that the front LED 318 is detected by the board 20, and the start address (Hs, Vs) set at Step S188 is output to a start setting circuit 241 in the board 20 (Step S194). This subroutine returns after the reading of the data in the trace block is started (Step S196). The reading of the data for the front LED 318 of the car 3 of ID No.0 is carried out in the data accumulating circuit 18 in the board 10 or in the data accumulating circuit 28 in the board 20.

By setting the start address (Hs, Vs) such that the position of the LED 318 (or 319) is located in the center of the trace block, the movement of the car 3 can securely be traced after one frame cycle independently of the running direction of the car 3, in other words, independently of the car 3 running in any angle in 360 degrees over the plane.

Particularly, since the correction amount set based on the running speed and the direction factor is considered as described later, the tracing can be made more secure. Instead of setting a specified traceable correction amount based on the preset highest speed of the car 3, the correction amount may be changed real-time depending upon the present running speed of the car 3 (obtained by dividing a difference between the detected positions in the last 2 frames by the frame cycle). This enables the front and rear LEDs 318 and 319 to be located as close to the center of the trace block as possible, thereby preventing the tracing error.

Figs. 21 to 23 are flowcharts showing the Interrupt II.

The Interrupt II is started in response to an interrupt signal generated each time the address designation of the trace block by the H-, V-counter 142 (242) is completed. First, it is judged whether the count value of the counter i is smaller than 7 (Step S210). If this count value is not smaller than 7 (YES in Step S210), this routine returns upon the judgment that the tracing has been completed within one frame.

First, the position of the front LED 318 of the car 3 of ID No.0 is detected. If the count value of the counter i is smaller than 7 (NO in Step S210), the dot number is read from the dot counter 183 (Step S212). It is then judged whether the dot number is 0 (Step S214). If the dot number is 0, a position tracing error flag PEF is set (Step S216), and (Hc, Vc) = (-1, -1) are set as a specific position data (Step S218). A position tracing error can be confirmed by this data or by monitoring the error flag PEF, and an alarm is given upon detecting the tracing error. Alternately, the trace block may be made larger than a predetermined size in case of such errors, so that the tracing can be further continued.

On the other hand, if the dot number is not 0, the coordinates accumulation data in the H- and V-directions are read from the latch circuit 182 upon the assumption that the tracing was completely made (Step S220). At this time, if the latch circuit 182 undergoes an overflow (NO in Step S220), the coordinates accumulation data are corrected (Step S224). This correction is made, for example, based on the previous center of gravity position of the LED 318 (or 319) and the

$$Hs = FH[i] - (BS/2) + AFH[i]$$

$$Vs = FV[i] - (BS/4) + AFV[i]$$

the count value i is incremented by 1 (Step S278), and the counting is started (Step S252), thereby repeating the aforementioned operations for the trace block of the next car 3.

Referring back to Fig. 16, after transferring the calculated values upon the completion of the Interrupt II, the identification number ID No.i is set to 0 (Step S70), and any more interrupt is prohibited (Step S72). The position data of the front and rear LEDs 318 and 319, i.e., RFH[i], RFV[i] and RBH[i], RBV[i] are read from the buffer (Step S74). The interrupts are allowed again upon the completion of this reading (Step S76). Since the data transfer by the Interrupt II is repeated between Steps S68 and S90, Steps S72 and S76 are provided to prevent the reading of the erroneous data even if the reading of the data from the buffer and the data transfer by the Interrupt II are carried out at the same timing.

The relationship between the position of the car 3 and the front and rear LEDs 318, 319 is predetermined. For example, the position of the car 3 may be an intermediate position of the front and rear LEDs 318 and 319. Upon determining the position of the car 3, the race development data, i.e., a goal position data and the speed data are set (Step S78). The goal position data is given to each car, and is a position data for designating passing points on the race track RC at specified intervals.

The running direction of the car 3 is calculated based on the present goal position and the detected position of the car 3 (Step S80). Further, a direction correction amount of the car 3 is calculated based on a target direction (direction toward the goal position) and the facing direction of the car 3 (which is calculated based on the positions of the front and rear LEDs 318 and 319 of the car 3). If the goal direction is calculated based on the data in three points: the present position, the next position and the further next position, the car 3 is capable of running more smoothly along the predetermined course. The speed and the direction are instructed to the car 3 based only on a goal speed data. More specifically, the speed instruction is given to one of the specific wheels, e.g., the motor 313 for driving the wheel 311, and the direction instruction is given in the form of a speed difference from the rotating speed of the motor 313. The direction can also be controlled by individually instructing the rotating speeds to the respective motors 313 and 314.

The obtained goal speed data is transmitted to the car 3 of the corresponding ID number via the transmission LEDs 7 (Step S82), and the count value of the counter *i* is incremented by 1 (Step S84). It is then judged whether the count value of the counter *i* is larger than 7 (Step S86). This routine returns to Step S72 if this count value is not larger than 7. If this count value is larger than 7, a system reset signal is checked (Step S88). The system reset signal is output in the case where an abnormality occurs in the system or when the race finishes.

If the system reset signal is not reset (NO in Step S90), this routine returns to Step S70 in which the count value of the counter *i* is set to "0". In this way, the running control for the cars 3 is continued until the race finishes. On the other hand, if the system reset signal is reset, this routine ends upon the judgment that the race has finished.

Although the initial position recognition (Steps S46 and S54) and the position detection during the tracing are performed by the different circuits in this embodiment, they may be performed by the single circuit. Further, although the position recognition is performed by individually turning on the front and rear LEDs 318 and 319 in the initial position recognition, it may be performed as follows. First, only the front LED 318 is turned on, and the front and rear LEDs 318 and 319 are turned on at a next timing. The position of the rear LED 319 is recognized by omitting the already recognized position of the front LED 318. This method requires only three kinds of control signals for the front and rear LEDs 318 and 319: one for turning the both LEDs 318 and 319 off, one for turning only the front LED 318 on, and one for turning the both LEDs 318 and 319 on. Further, a waiting period may be set based on the factor other than the frame in order to prevent a delay between the timing at which the front and rear LEDs 318 and 319 are turned on and the image pick-up timing so that the image can be securely picked up while the LEDs 318 and 319 are on.

Although members for emitting and receiving infrared radiations are used as communication means between the car 3 and the machine main body in the foregoing embodiment, members for transmitting and receiving radio waves or ultrasonic waves may also be used.

Although the cars performing a car race are controlled in the foregoing embodiment, the invention is not limited to this. The invention may be applied to another race game such as a horse race or a boat race, or may be applied to control a specific movement of one movable object.

Further, the invention is not limited to the control for the movable object on the surface (including a curved surface), but may be applied to a control for a movable object which moves linearly along a line, fly or floats in the air or in the liquid.

Further, in the foregoing embodiments, when a portion of the trace block comes outside the frame memory, a new trace block is set in the opposite frame memory to enable tracing. However, a new trace block may be set when the trace block goes beyond the border line. Alternatively, a new trace block may be set when the running car 3 comes across the border line.

Although the trace block is used to detect the position of the running car 3 in the foregoing embodiment, the invention is not limited to this. The frame memory may be integrally scanned to detect the position, instead of the use of trace

a calculating portion which calculates a position of the movable object based on the counted number and the accumulated coordinate values.

6. A position detecting system as defined in claim 3, wherein the designator includes:
a moved amount calculating portion which calculates a moved amount of the movable object based on the calculated position of the movable object; and
a designating portion which designates an address block based on a previously calculated position of the movable object and the calculated moved amount.

7. A position detecting system as defined in claim 1, wherein each of the first and second light sensors is provided with a lens for focusing a light image on a surface of the light sensor.

8. A position detecting system as defined in claim 1, wherein the light emitter is operable to emit light lying outside a frequency band for visible radiations; and each of the first and second light sensors is operable to receive only light lying in the same frequency band of light emitted by the light emitter.

FIG. 1

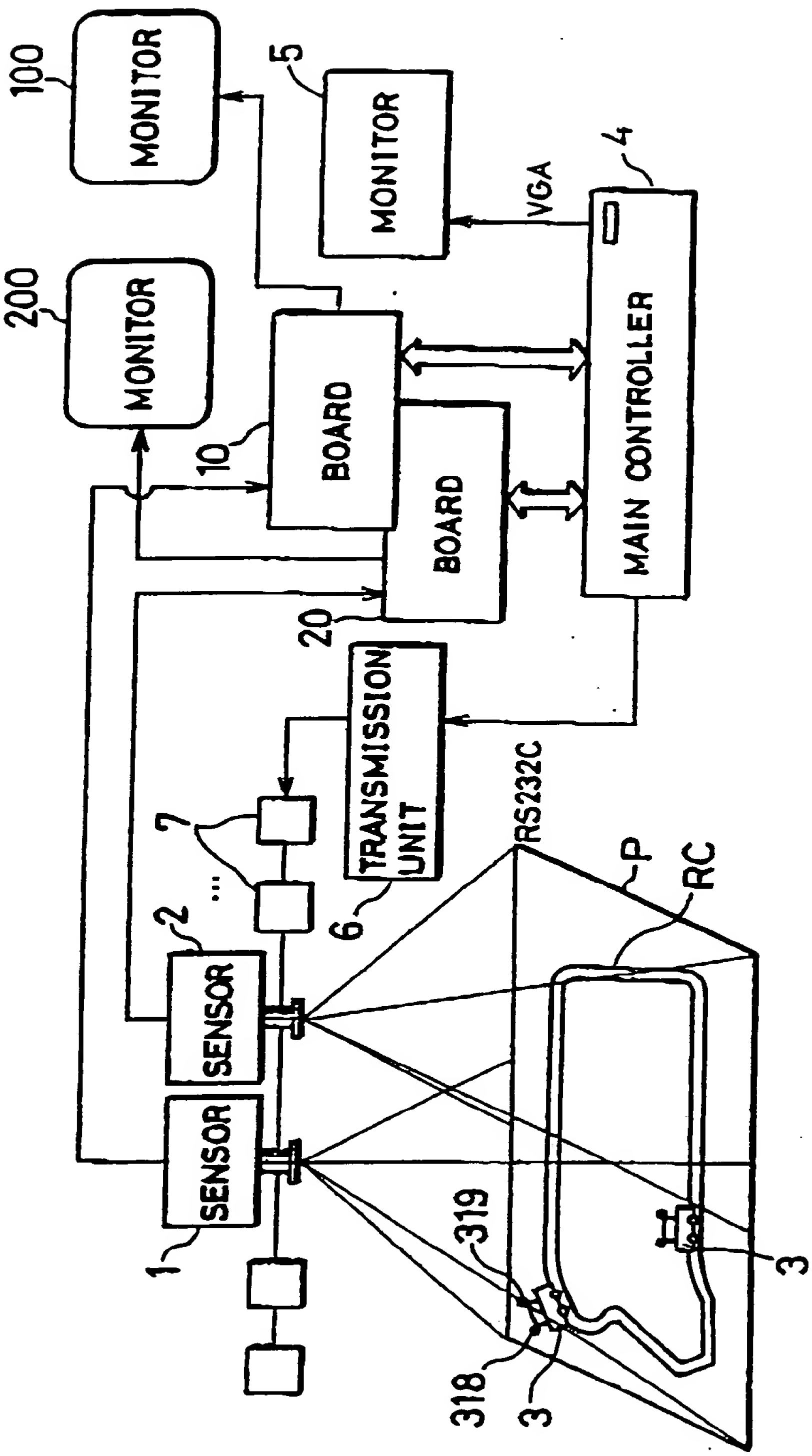

100
MONITOR
200
MONITOR
5
MONITOR
VGA
4
10
BOARD
BOARD
20
MAIN CONTROLLER
TRANSMISSION UNIT
6
RS232C
7
2
SENSOR
SENSOR
1
P
RC
319
318
3
3

FIG. 2

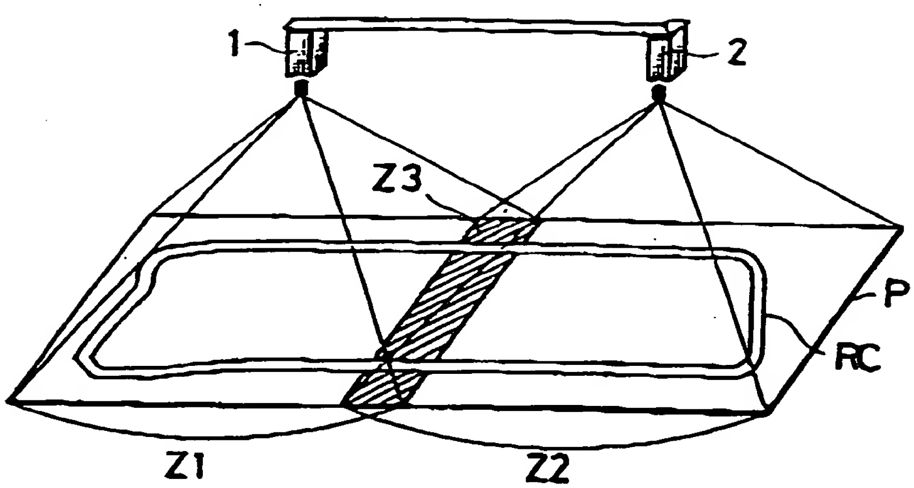


FIG. 3

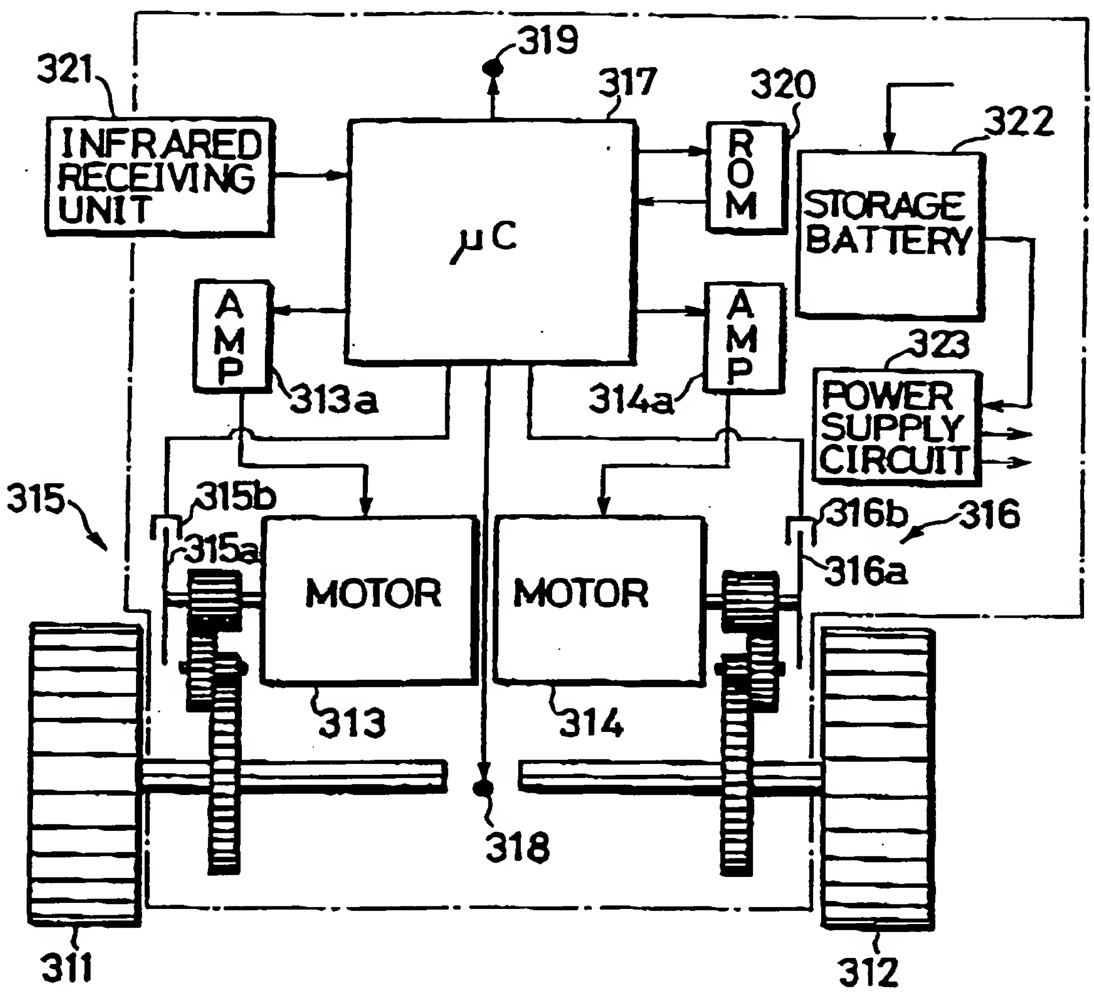

321
INFRARED RECEIVING UNIT
319
317
μC
320
ROM
322
STORAGE BATTERY
AMP
313a
AMP
314a
323
POWER SUPPLY CIRCUIT
315
315b
315a
MOTOR
MOTOR
316b
316
316a
313
314
318
311
312

FIG. 4

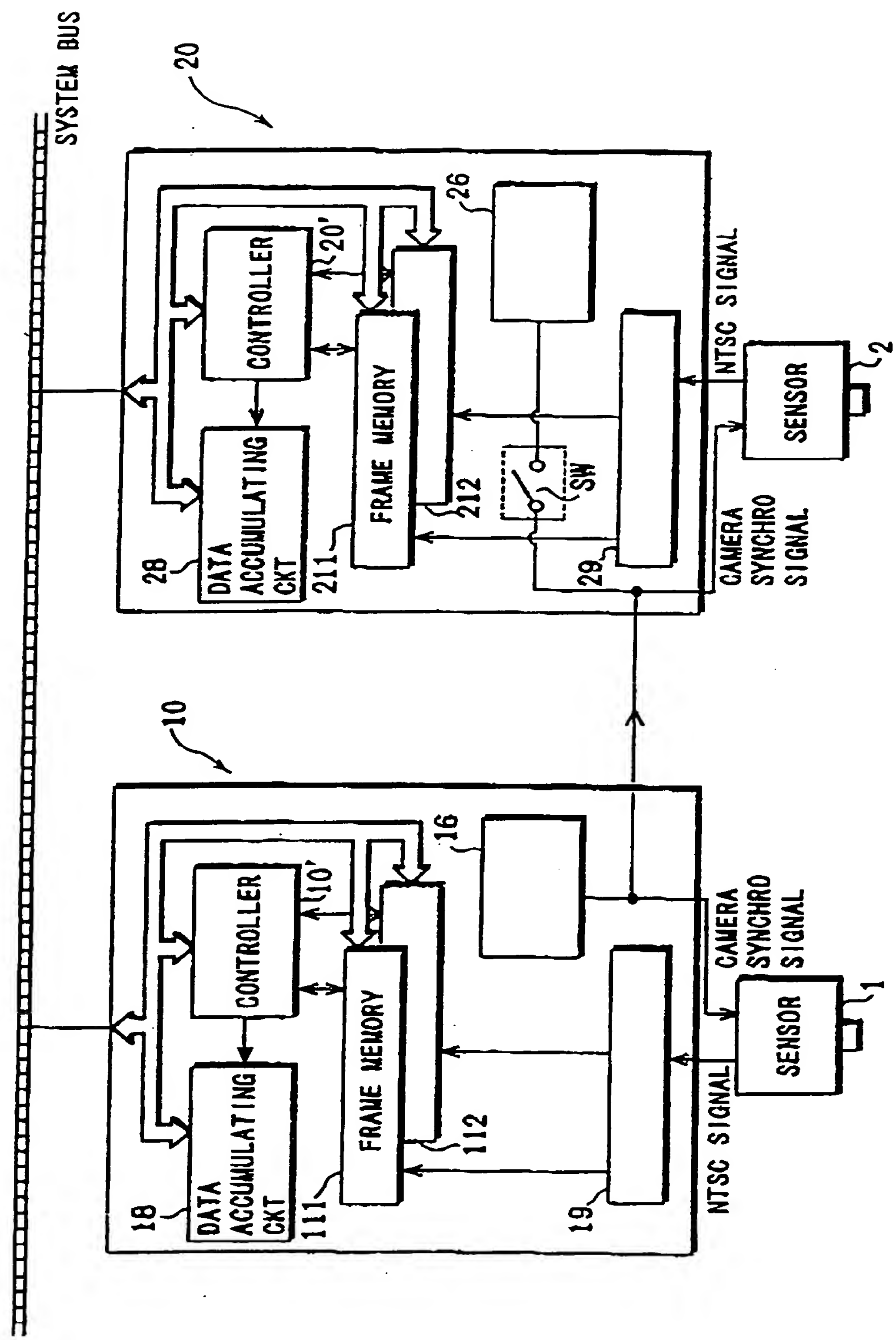

SYSTEM BUS
20
10
CONTROLLER
20'
10'
DATA ACCUMULATING CKT
FRAME MEMORY
26
16
28
18
211
212
111
112
SW
29
19
NTSC SIGNAL
CAMERA SYNCHRO SIGNAL
SENSOR
SENSOR
2
1

FIG. 5

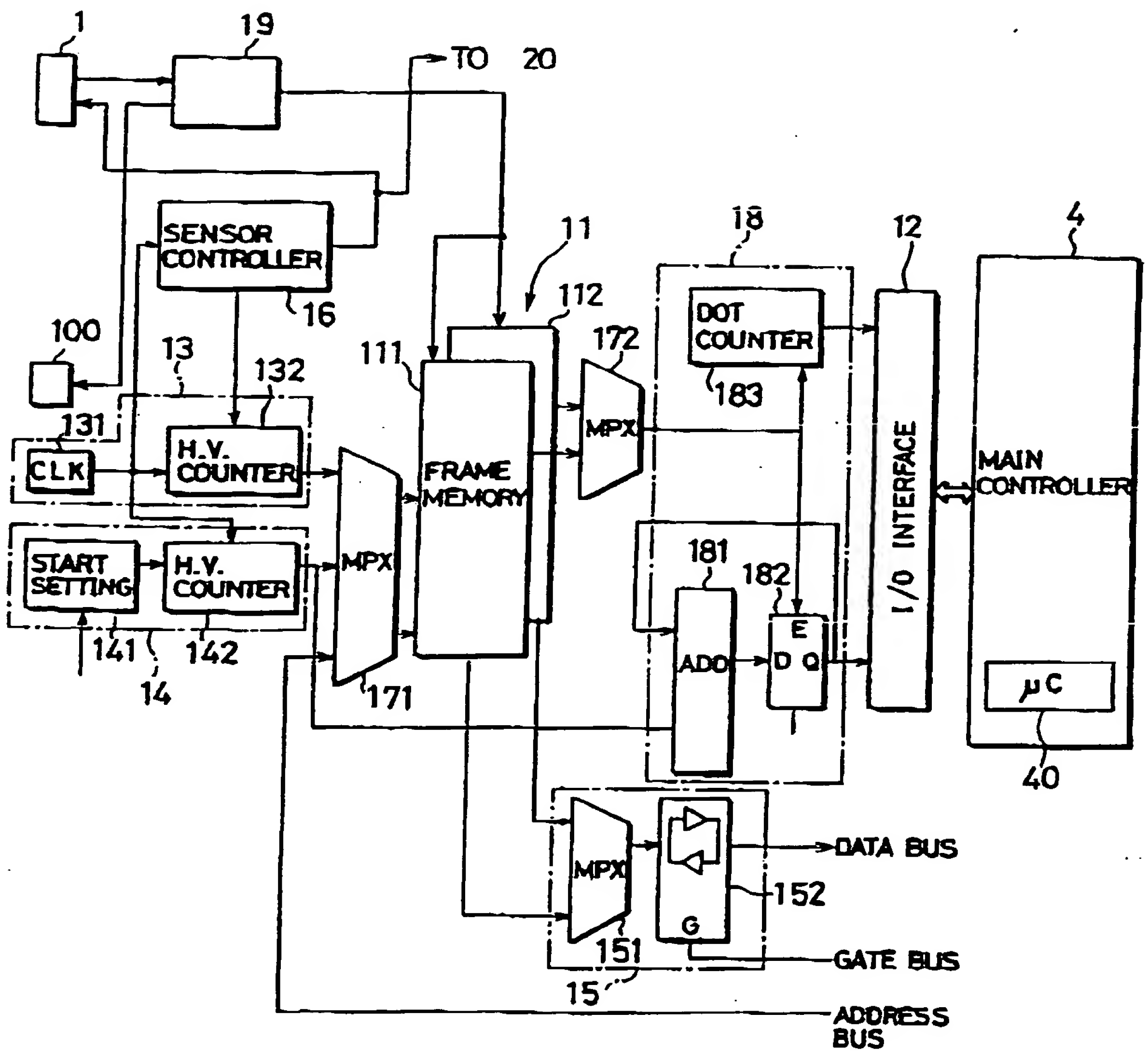

TO 20
SENSOR CONTROLLER
CLK
H.V. COUNTER
START SETTING
H.V. COUNTER
MPX
FRAME MEMORY
MPX
DOT COUNTER
ADD
E
D Q
I/O INTERFACE
MAIN CONTROLLER
μC
MPX
G
DATA BUS
GATE BUS
ADDRESS BUS

FIG. 6

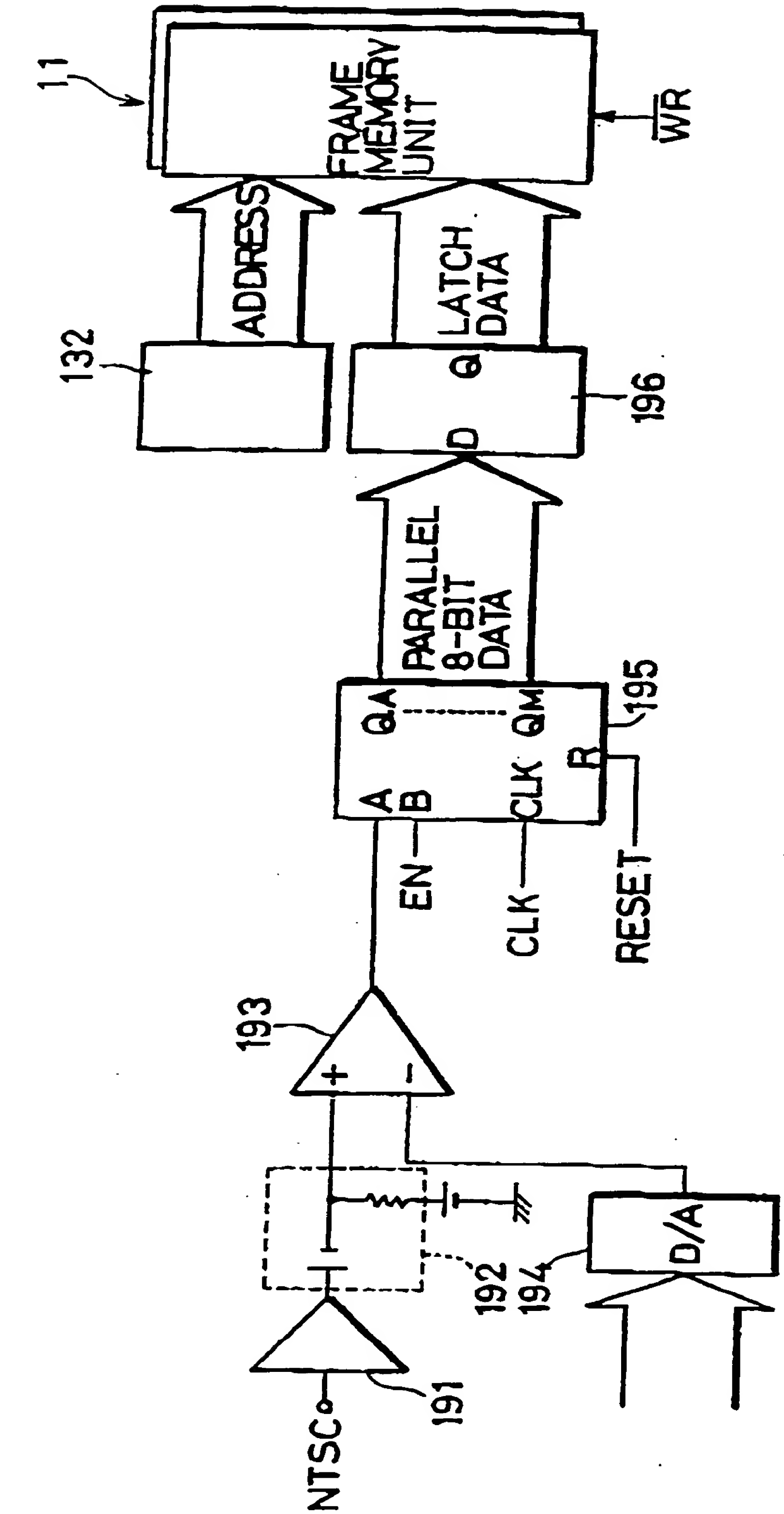

11
FRAME MEMORY UNIT
WR
132
ADDRESS
LATCH DATA
Q
D
196
PARALLEL 8-BIT DATA
QA
QM
A
B
CLK
R
195
EN
CLK
RESET
193
+
−
NTSC
191
192
194
D/A

FIG. 7

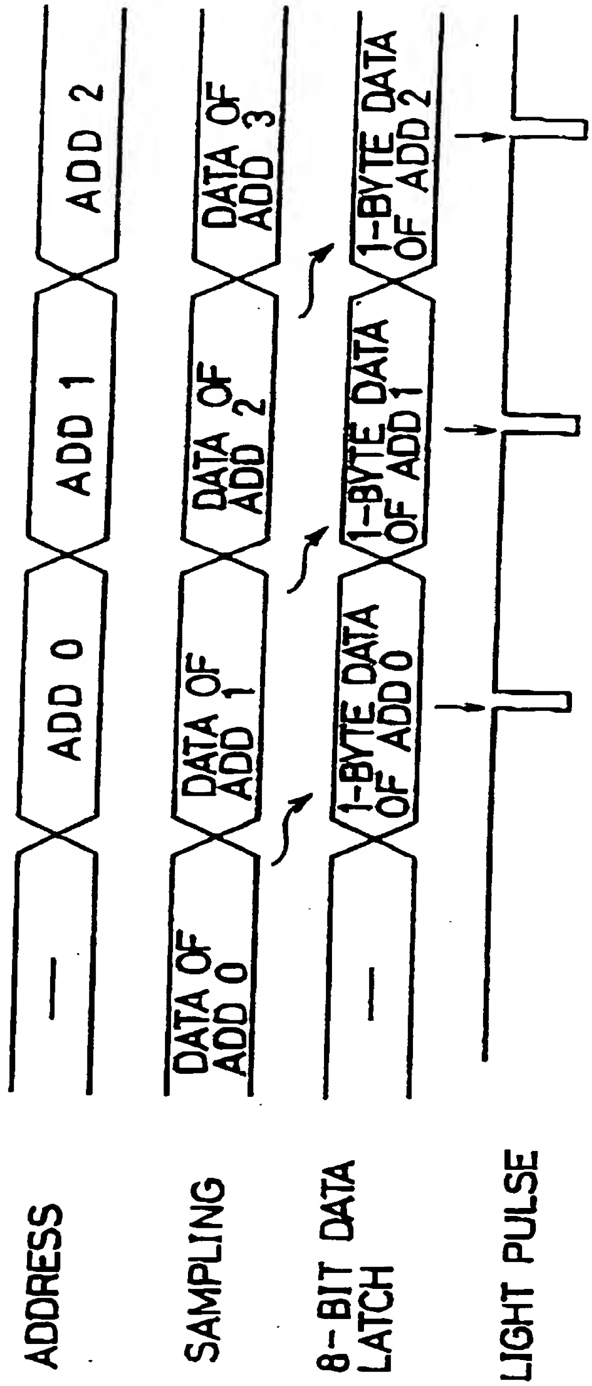

ADDRESS
SAMPLING
8-BIT DATA LATCH
LIGHT PULSE
ADD 0
ADD 1
ADD 2
DATA OF ADD 0
DATA OF ADD 1
DATA OF ADD 2
DATA OF ADD 3
1-BYTE DATA OF ADD 0
1-BYTE DATA OF ADD 1
1-BYTE DATA OF ADD 2

FIG. 8A

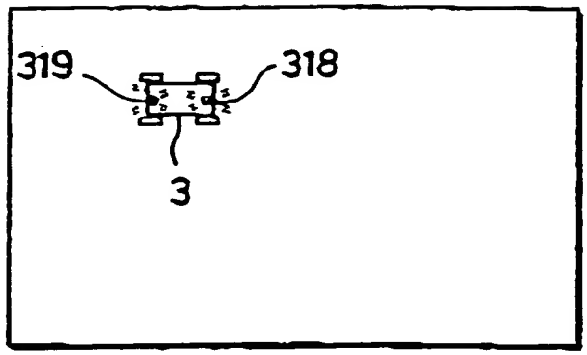


FIG. 8B

FIG. 8C

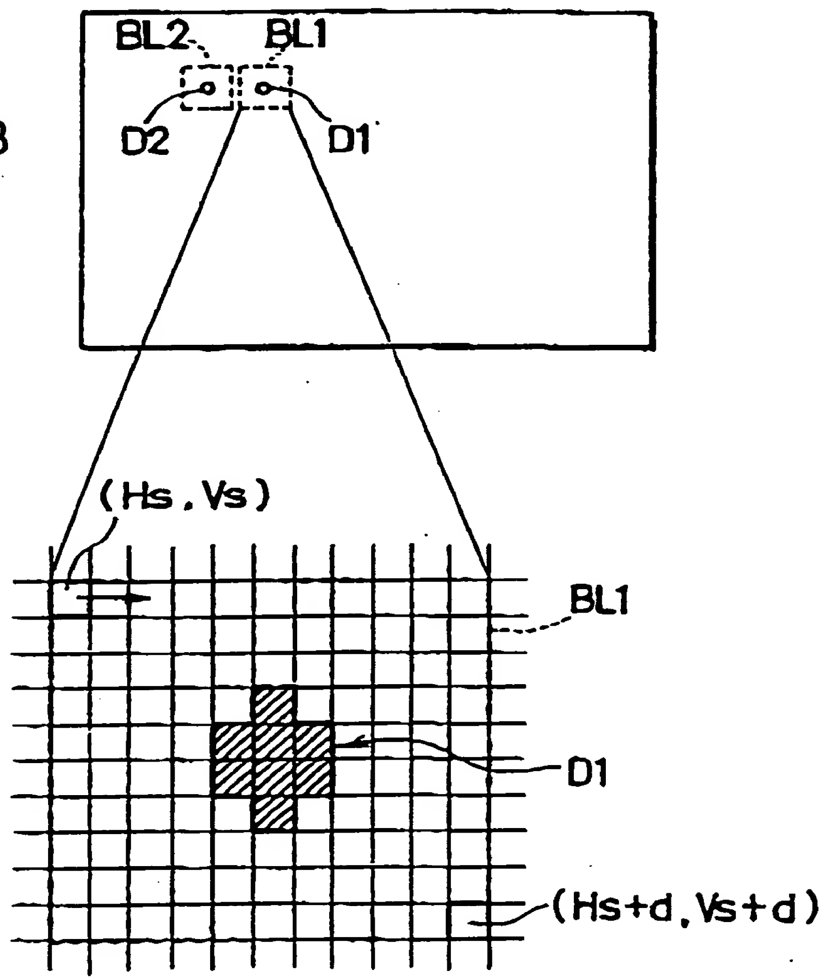


FIG. 9

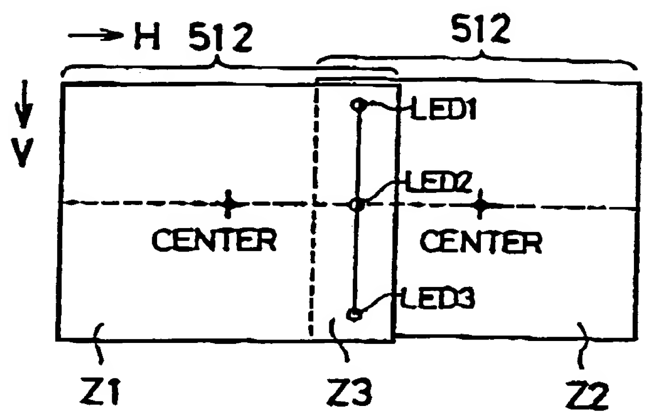

H
512
512
V
LED1
LED2
LED3
CENTER
CENTER
Z1
Z3
Z2

FIG. 10

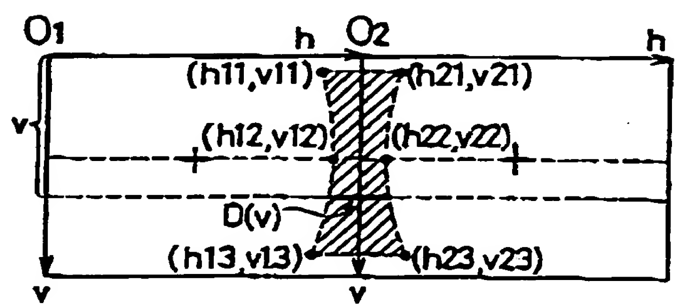

O1
h
O2
h
(h11,v11)
(h21,v21)
v
(h12,v12)
(h22,v22)
D(v)
(h13,v13)
(h23,v23)
v
v

FIG. 11

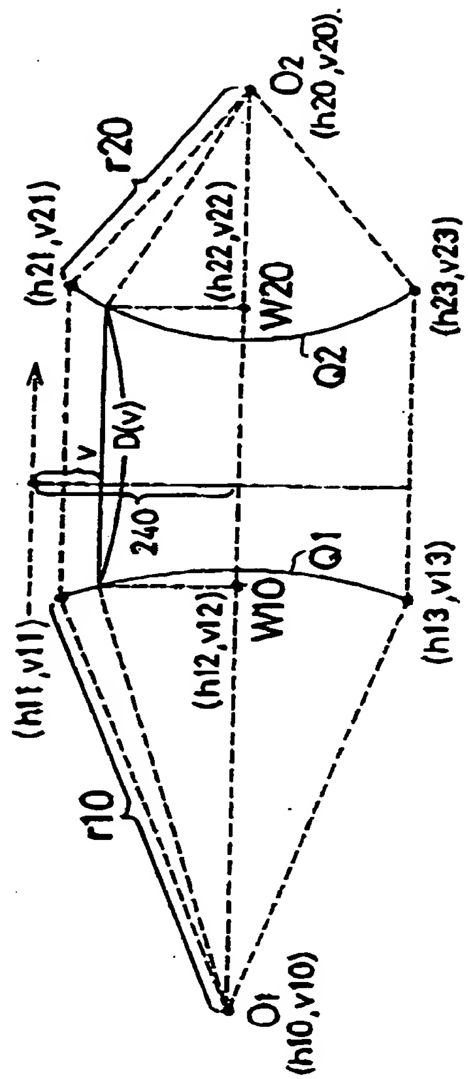

O2
(h20,v20)
r20
(h21,v21)
(h22,v22)
W20
(h23,v23)
Q2
v
D(v)
240
Q1
W10
(h11,v11)
(h12,v12)
(h13,v13)
r10
O1
(h10,v10)

FIG. 12A

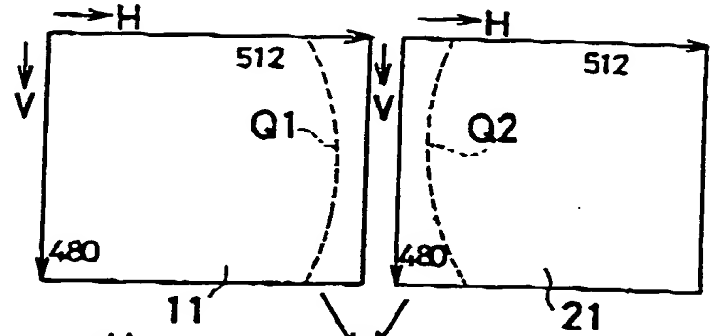


FIG. 12B

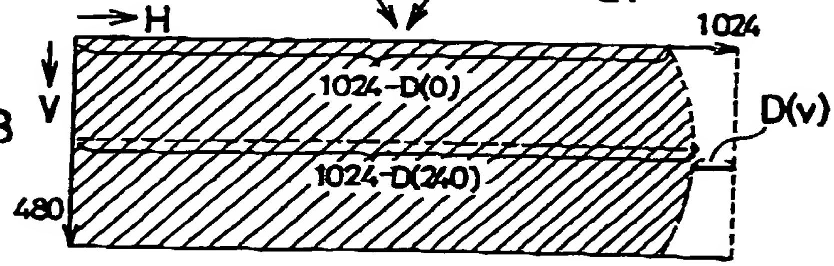


FIG. 13

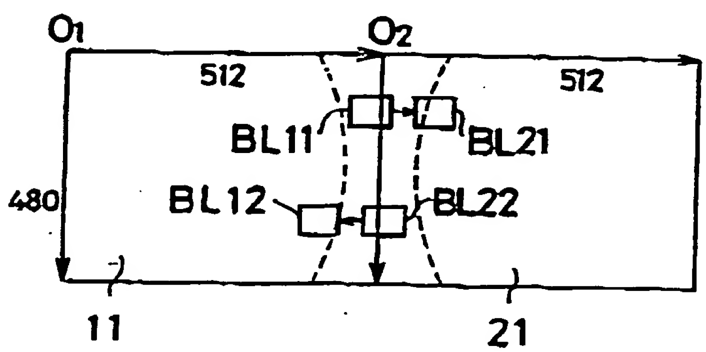


FIG. 14

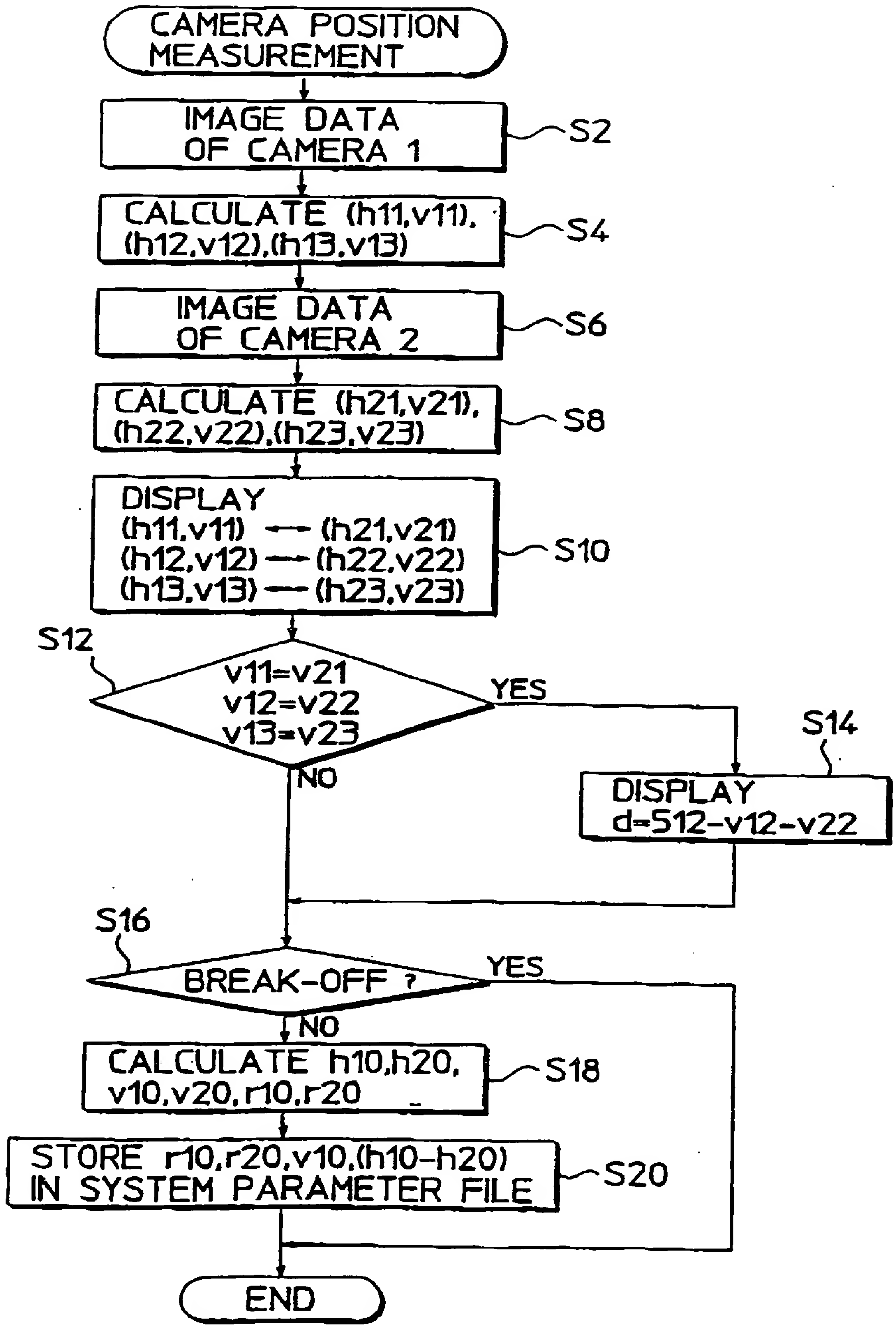

CAMERA POSITION MEASUREMENT
IMAGE DATA OF CAMERA 1
S2
CALCULATE (h11,v11), (h12,v12),(h13,v13)
S4
IMAGE DATA OF CAMERA 2
S6
CALCULATE (h21,v21), (h22,v22),(h23,v23)
S8
DISPLAY
(h11,v11) ← (h21,v21)
(h12,v12) ← (h22,v22)
(h13,v13) ← (h23,v23)
S10
S12
v11=v21
v12=v22
v13=v23
YES
NO
S14
DISPLAY d=512-v12-v22
S16
BREAK-OFF ?
YES
NO
CALCULATE h10,h20, v10,v20,r10,r20
S18
STORE r10,r20,v10,(h10-h20) IN SYSTEM PARAMETER FILE
S20
END

FIG.15

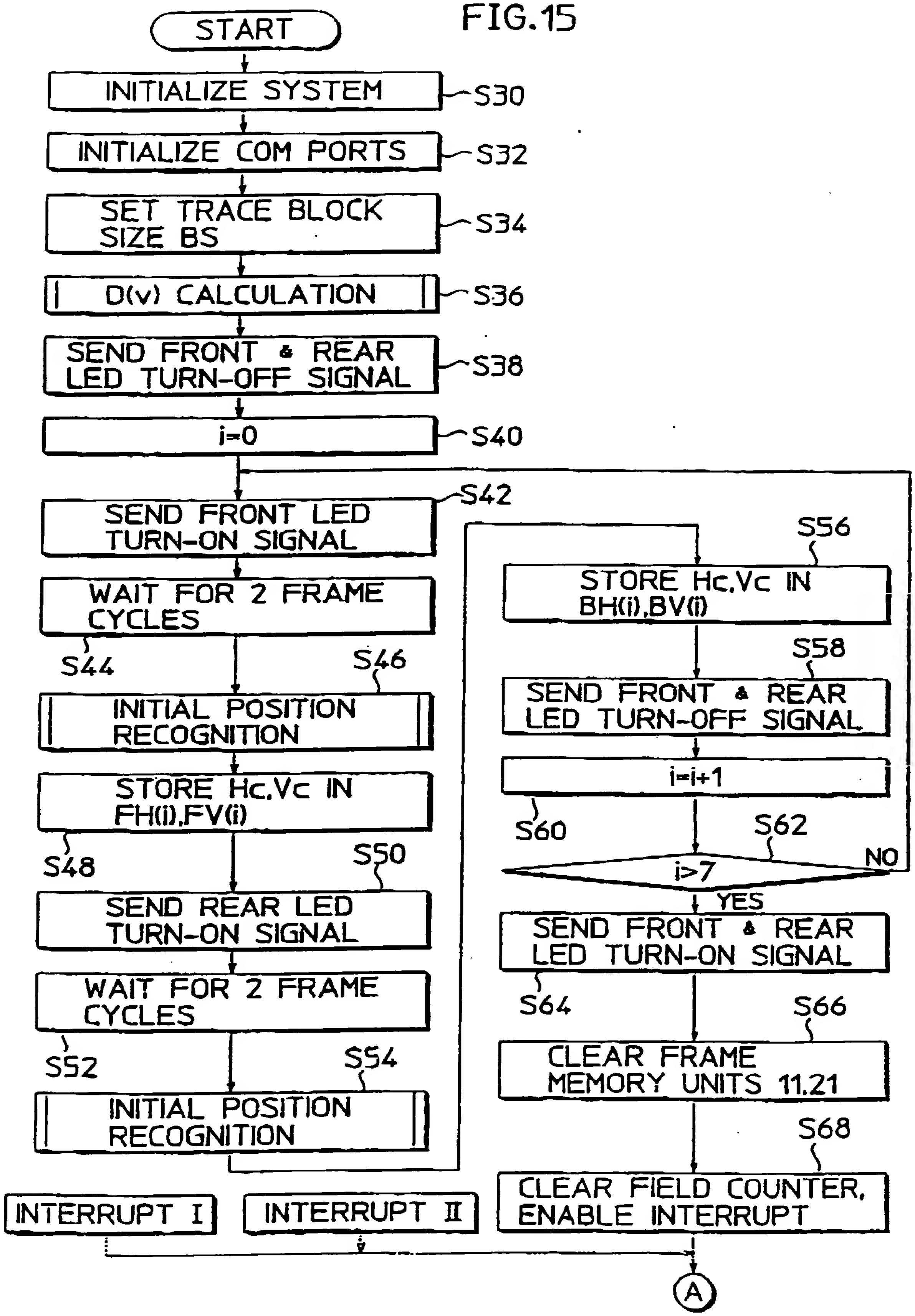

START
INITIALIZE SYSTEM
S30
INITIALIZE COM PORTS
S32
SET TRACE BLOCK SIZE BS
S34
D(v) CALCULATION
S36
SEND FRONT & REAR LED TURN-OFF SIGNAL
S38
i=0
S40
SEND FRONT LED TURN-ON SIGNAL
S42
WAIT FOR 2 FRAME CYCLES
S44
S46
INITIAL POSITION RECOGNITION
STORE Hc,Vc IN FH(i),FV(i)
S48
S50
SEND REAR LED TURN-ON SIGNAL
WAIT FOR 2 FRAME CYCLES
S52
S54
INITIAL POSITION RECOGNITION
S56
STORE Hc,Vc IN BH(i),BV(i)
S58
SEND FRONT & REAR LED TURN-OFF SIGNAL
i=i+1
S60
S62
i>7
NO
YES
SEND FRONT & REAR LED TURN-ON SIGNAL
S64
S66
CLEAR FRAME MEMORY UNITS 11,21
S68
CLEAR FIELD COUNTER, ENABLE INTERRUPT
INTERRUPT I
INTERRUPT II
A

FIG.16

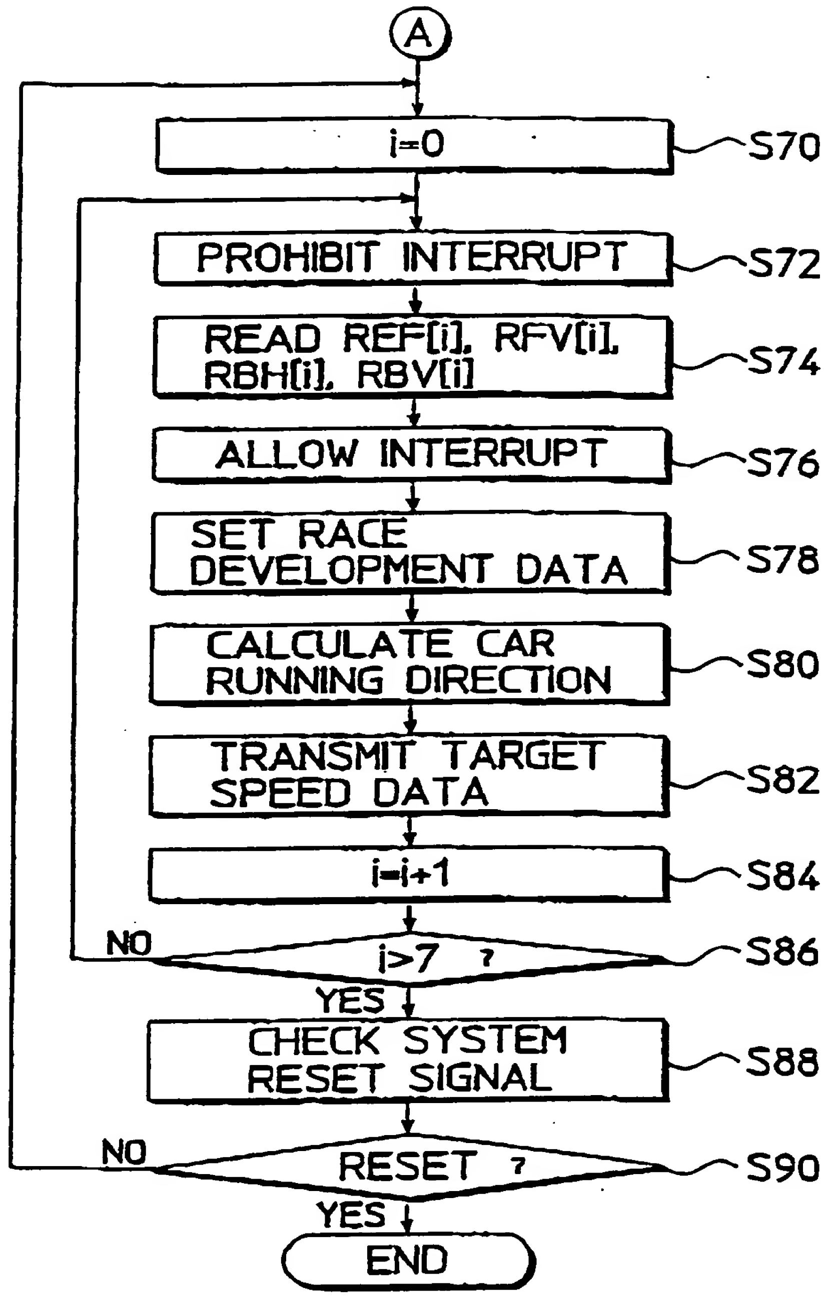

A
i=0
S70
PROHIBIT INTERRUPT
S72
READ REF[i], RFV[i], RBH[i], RBV[i]
S74
ALLOW INTERRUPT
S76
SET RACE DEVELOPMENT DATA
S78
CALCULATE CAR RUNNING DIRECTION
S80
TRANSMIT TARGET SPEED DATA
S82
i=i+1
S84
NO
i>7 ?
S86
YES
CHECK SYSTEM RESET SIGNAL
S88
NO
RESET ?
S90
YES
END

FIG. 17

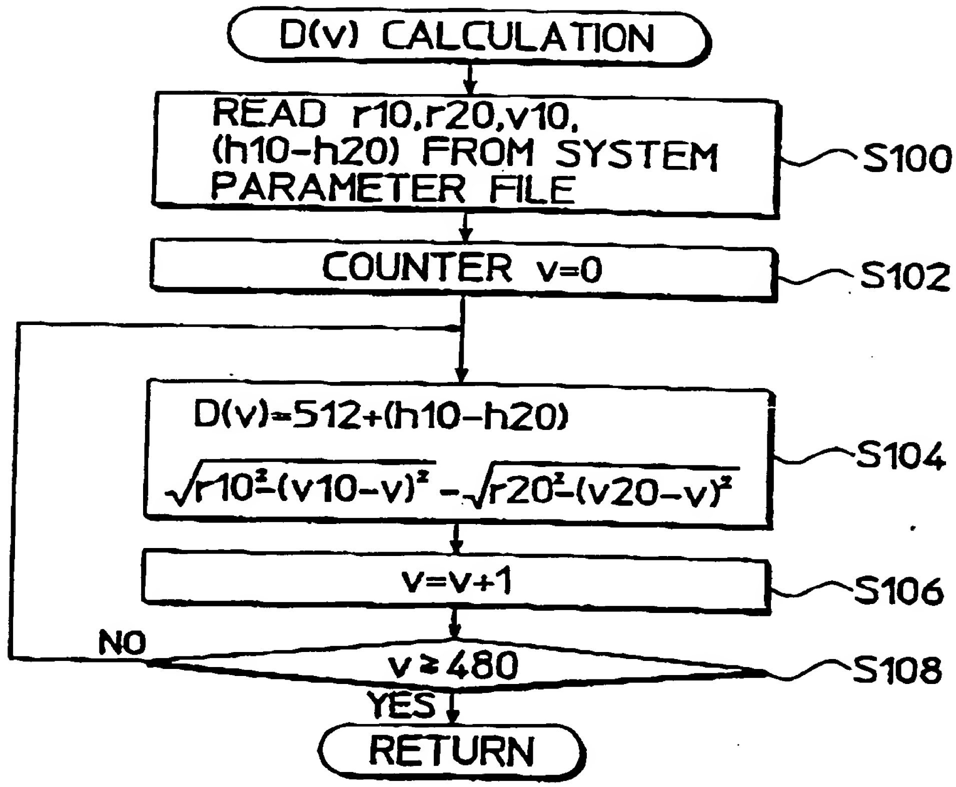

D(v) CALCULATION
READ r10,r20,v10,
(h10-h20) FROM SYSTEM
PARAMETER FILE
S100
COUNTER v=0
S102
D(v)=512+(h10-h20)
$\sqrt{r10^2-(v10-v)^2}-\sqrt{r20^2-(v20-v)^2}$
S104
v=v+1
S106
NO
v≥480
S108
YES
RETURN

FIG. 18

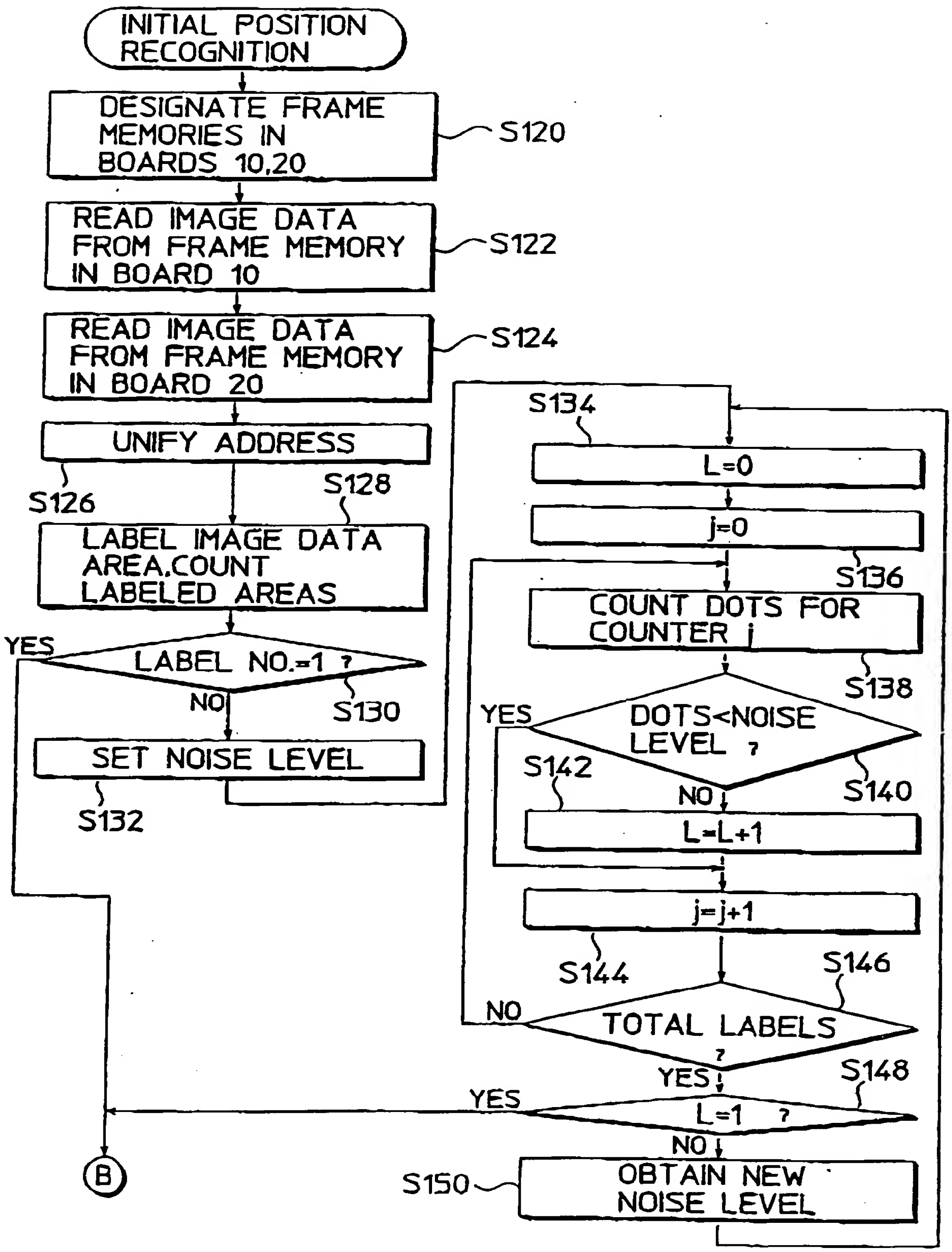

INITIAL POSITION RECOGNITION
DESIGNATE FRAME MEMORIES IN BOARDS 10,20
S120
READ IMAGE DATA FROM FRAME MEMORY IN BOARD 10
S122
READ IMAGE DATA FROM FRAME MEMORY IN BOARD 20
S124
UNIFY ADDRESS
S126
S128
LABEL IMAGE DATA AREA,COUNT LABELED AREAS
YES
LABEL NO.=1 ?
NO
S130
SET NOISE LEVEL
S132
S134
L=0
j=0
S136
COUNT DOTS FOR COUNTER j
S138
YES
DOTS<NOISE LEVEL ?
S142
NO
S140
L=L+1
j=j+1
S144
S146
NO
TOTAL LABELS ?
YES
S148
YES
L=1 ?
NO
B
S150
OBTAIN NEW NOISE LEVEL

FIG. 19

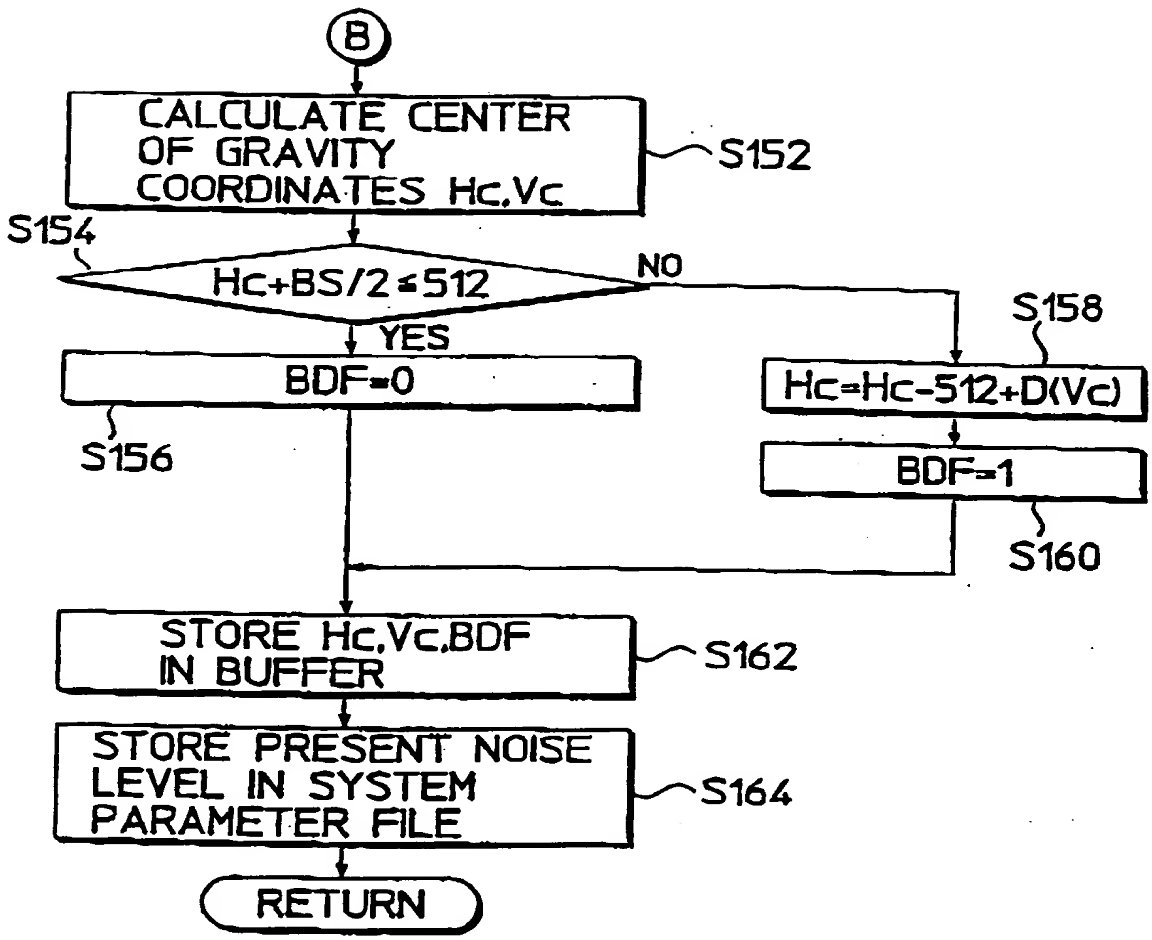

B
CALCULATE CENTER OF GRAVITY COORDINATES Hc,Vc
S152
S154
Hc+BS/2≤512
NO
YES
BDF=0
S156
S158
Hc=Hc-512+D(Vc)
BDF=1
S160
STORE Hc,Vc,BDF IN BUFFER
S162
STORE PRESENT NOISE LEVEL IN SYSTEM PARAMETER FILE
S164
RETURN

FIG.20

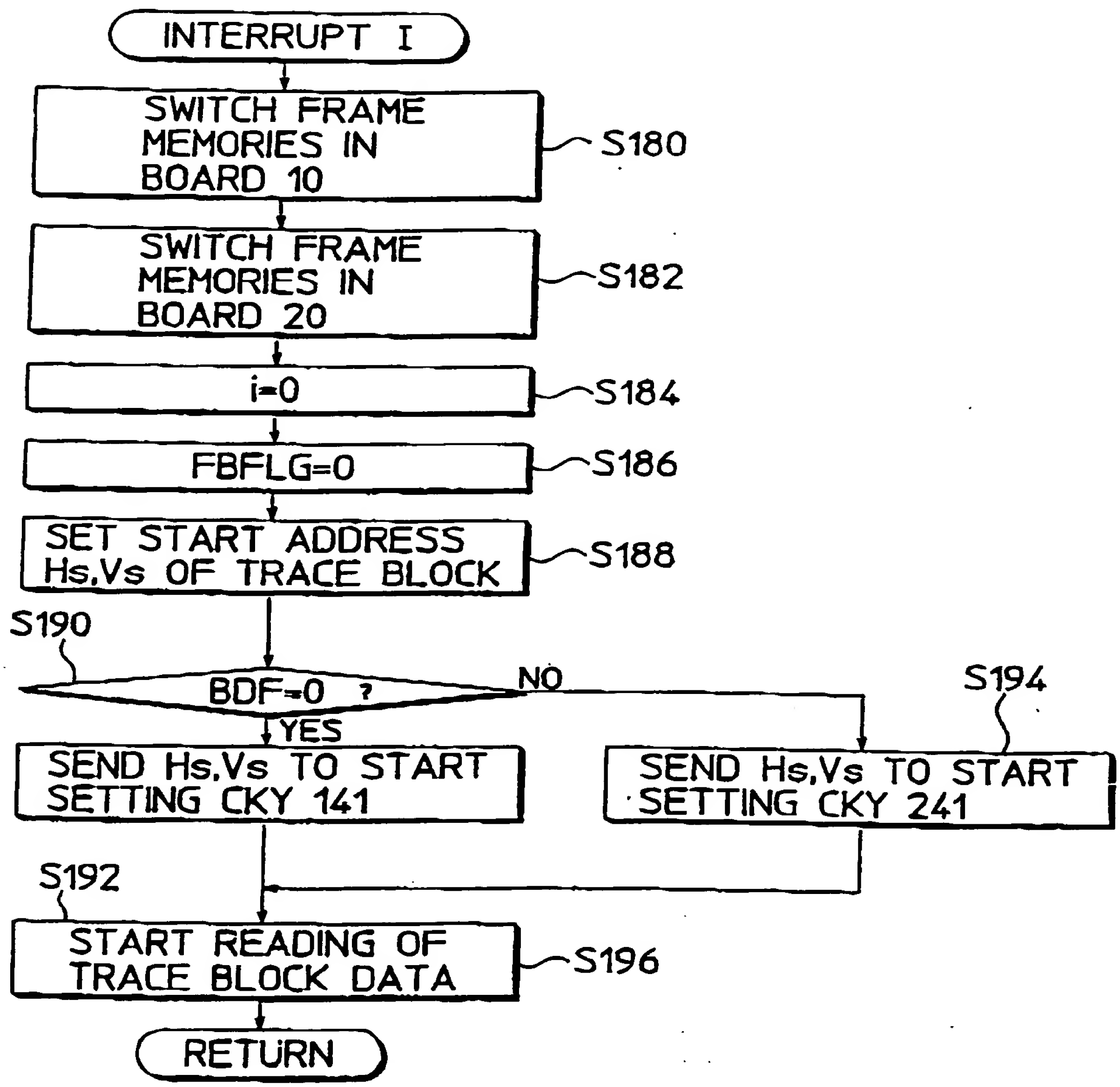

INTERRUPT I
SWITCH FRAME MEMORIES IN BOARD 10
S180
SWITCH FRAME MEMORIES IN BOARD 20
S182
i=0
S184
FBFLG=0
S186
SET START ADDRESS Hs,Vs OF TRACE BLOCK
S188
S190
BDF=0 ?
NO
YES
S194
SEND Hs,Vs TO START SETTING CKY 141
SEND Hs,Vs TO START SETTING CKY 241
S192
START READING OF TRACE BLOCK DATA
S196
RETURN

FIG. 21

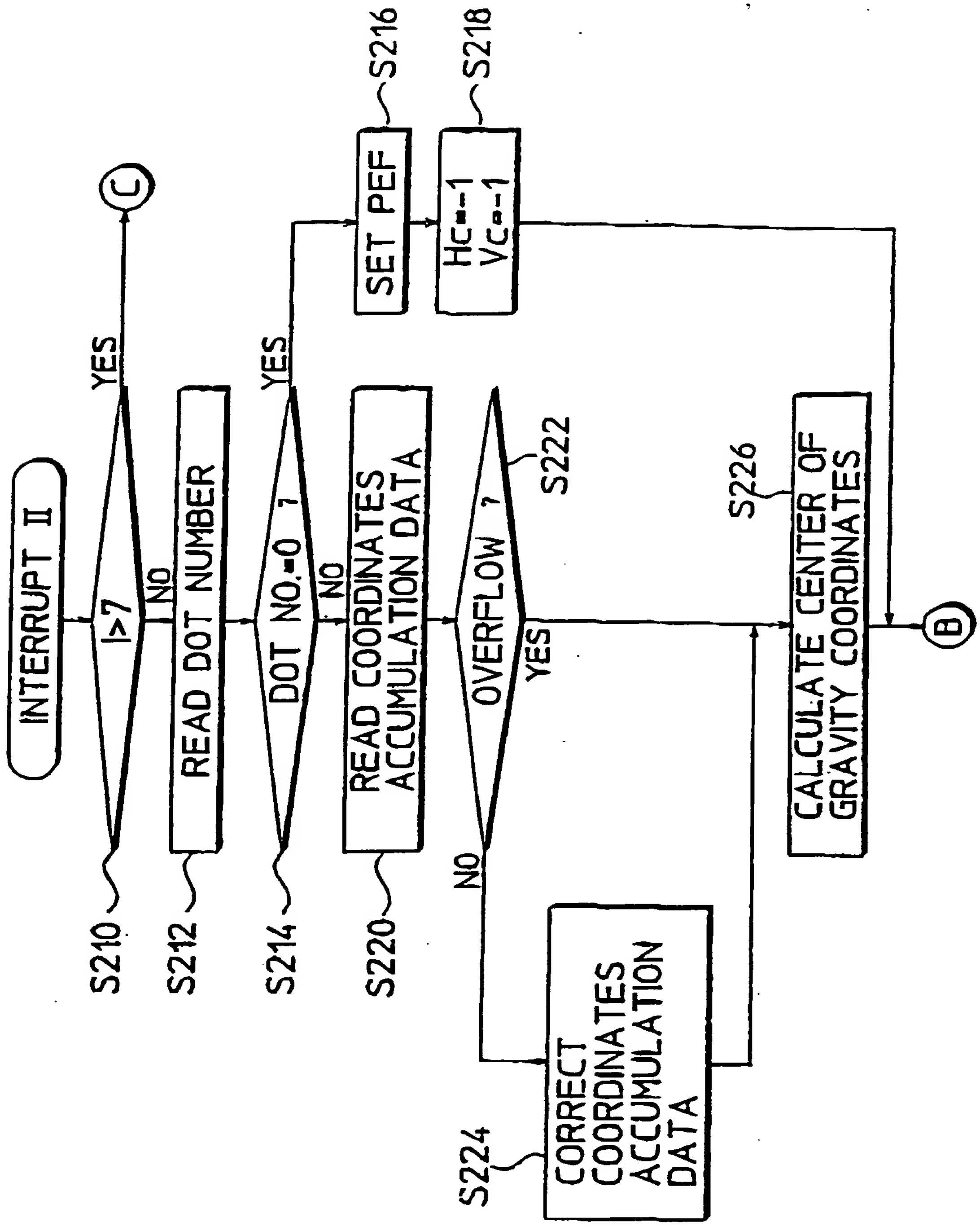

INTERRUPT II
I>7
YES
NO
C
S210
READ DOT NUMBER
S212
DOT NO.=0 ?
YES
NO
S214
SET PEF
S216
Hc=-1
Vc=-1
S218
READ COORDINATES ACCUMULATION DATA
S220
OVERFLOW ?
S222
YES
NO
CORRECT COORDINATES ACCUMULATION DATA
S224
CALCULATE CENTER OF GRAVITY COORDINATES
S226
B

FIG. 22

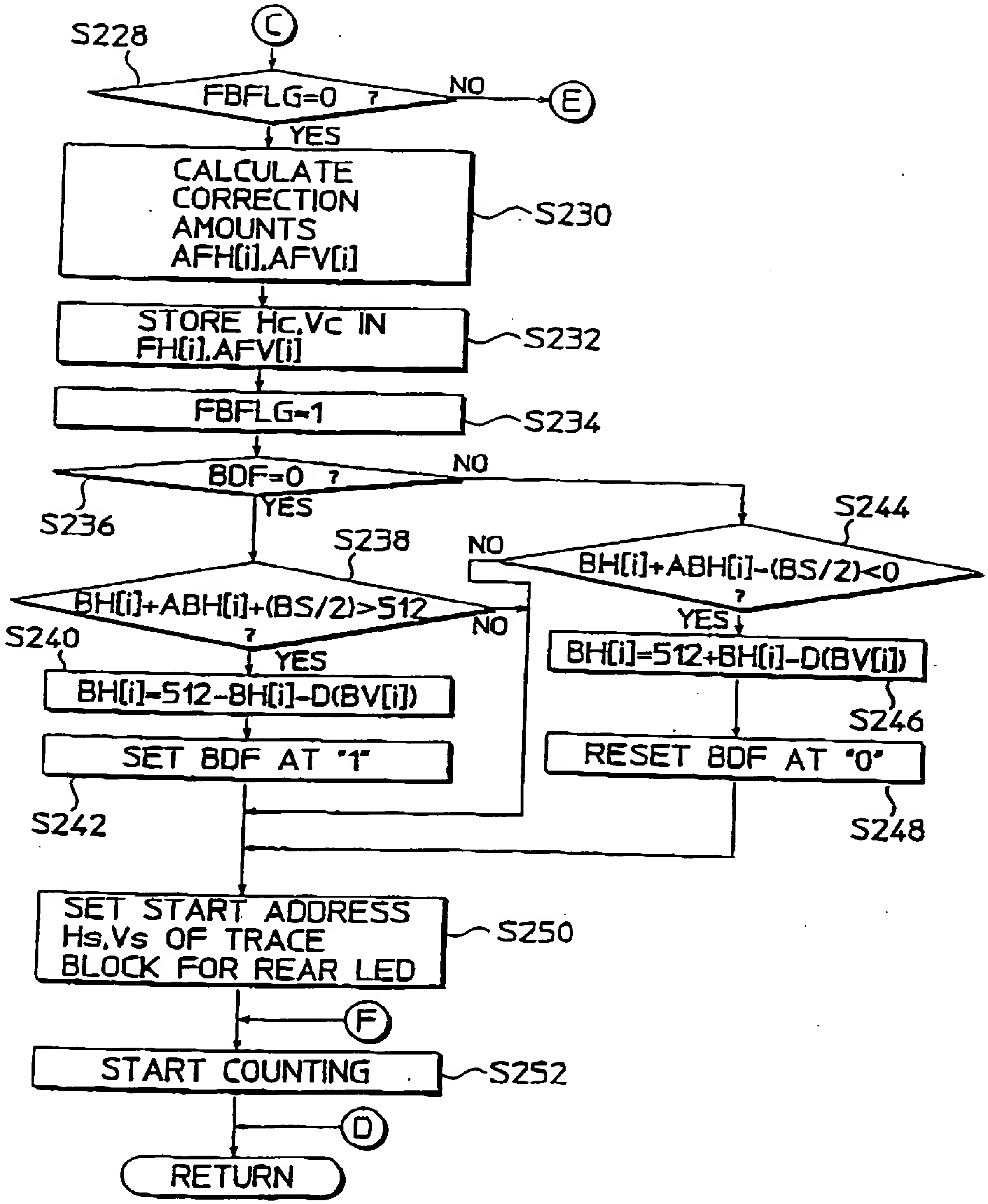

C
S228
FBFLG=0 ?
NO
E
YES
CALCULATE CORRECTION AMOUNTS AFH[i],AFV[i]
S230
STORE Hc,Vc IN FH[i],AFV[i]
S232
FBFLG=1
S234
BDF=0 ?
NO
YES
S236
S244
S238
NO
BH[i]+ABH[i]-(BS/2)<0 ?
BH[i]+ABH[i]+(BS/2)>512 ?
NO
S240
YES
YES
BH[i]=512+BH[i]-D(BV[i])
BH[i]=512-BH[i]-D(BV[i])
S246
SET BDF AT "1"
RESET BDF AT "0"
S242
S248
SET START ADDRESS Hs,Vs OF TRACE BLOCK FOR REAR LED
S250
F
START COUNTING
S252
D
RETURN

FIG. 23

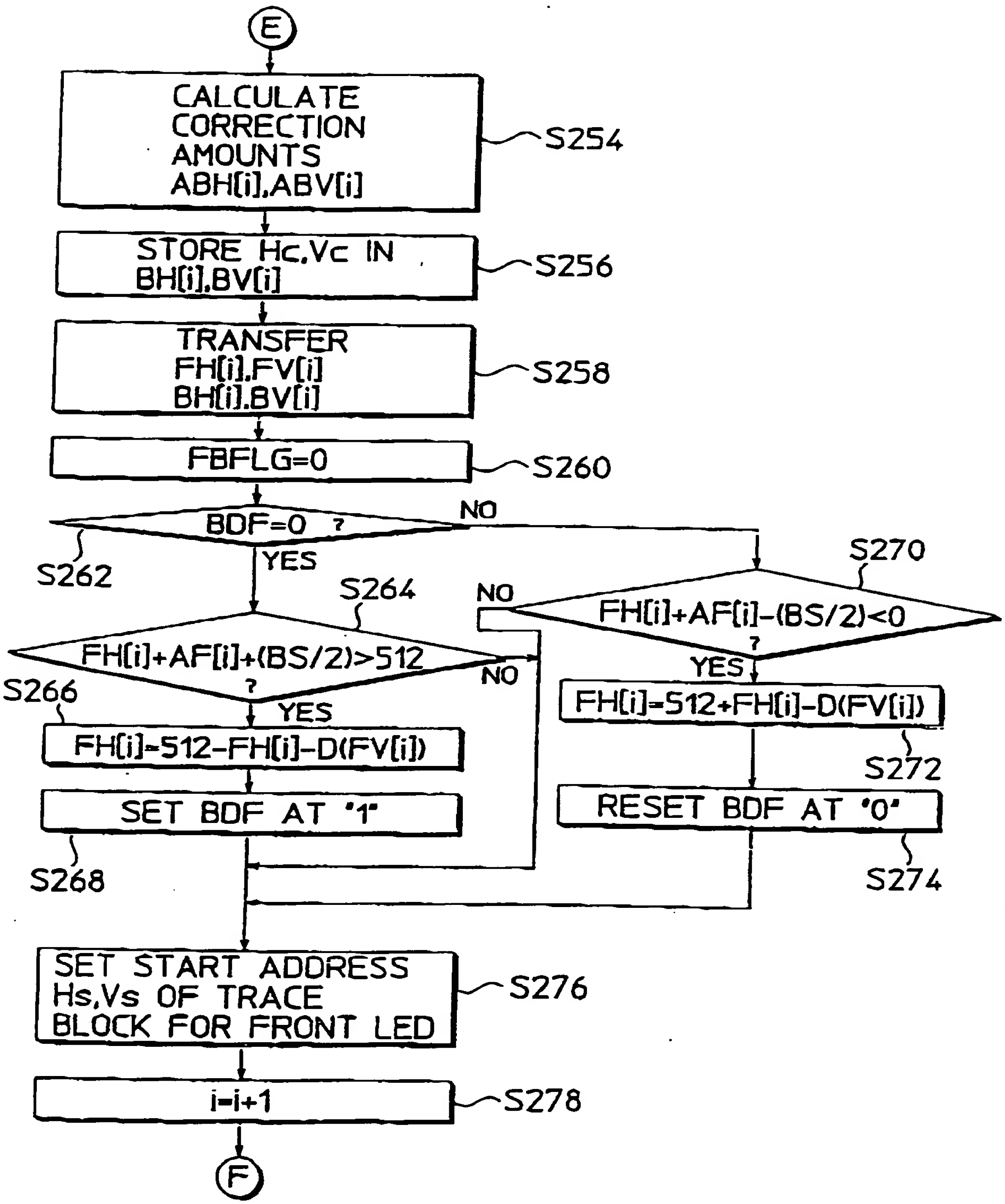

E
CALCULATE CORRECTION AMOUNTS ABH[i],ABV[i]
S254
STORE Hc,Vc IN BH[i],BV[i]
S256
TRANSFER FH[i],FV[i] BH[i],BV[i]
S258
FBFLG=0
S260
BDF=0 ?
S262
NO
YES
S270
FH[i]+AF[i]-(BS/2)<0 ?
NO
YES
S264
FH[i]+AF[i]+(BS/2)>512 ?
NO
YES
S266
FH[i]=512-FH[i]-D(FV[i])
FH[i]=512+FH[i]-D(FV[i])
S272
SET BDF AT '1'
S268
RESET BDF AT '0'
S274
SET START ADDRESS Hs,Vs OF TRACE BLOCK FOR FRONT LED
S276
i=i+1
S278
F

FIG. 24

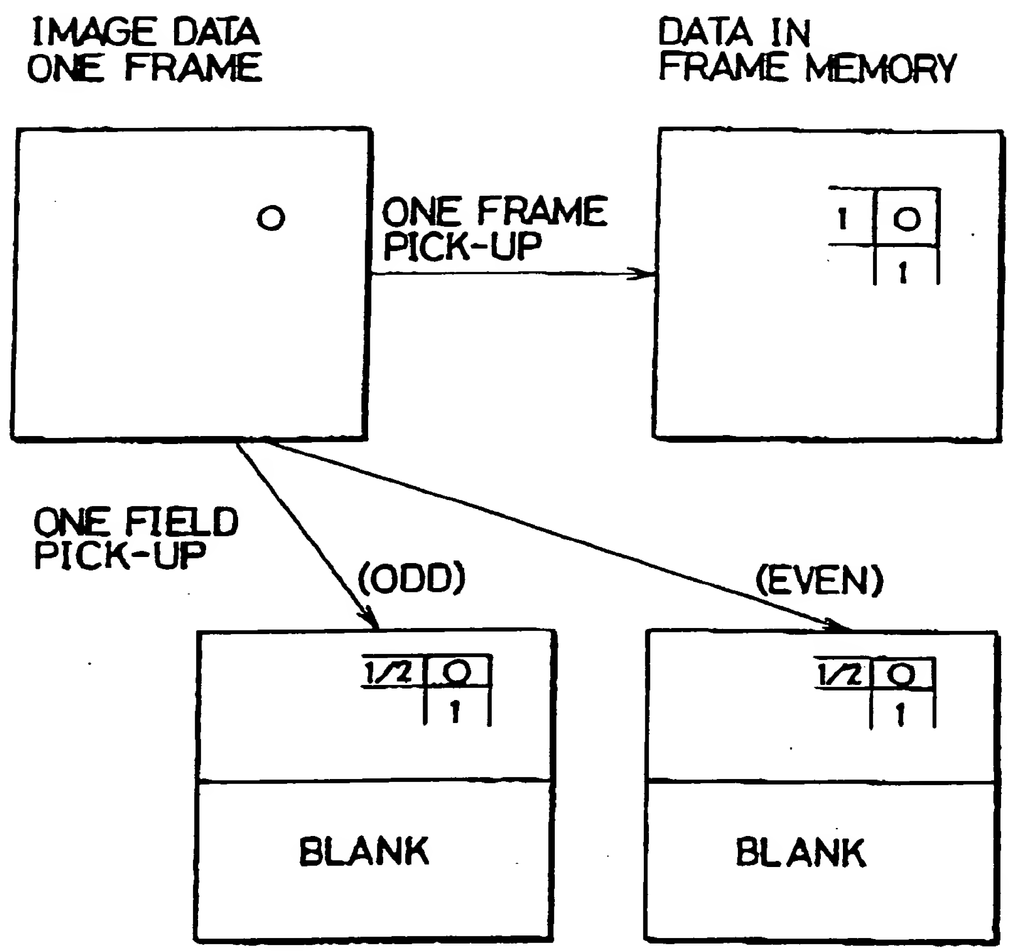


IMAGE DATA
ONE FRAME
DATA IN
FRAME MEMORY
ONE FRAME
PICK-UP
1
O
1
ONE FIELD
PICK-UP
(ODD)
(EVEN)
1/2
O
1
1/2
O
1
BLANK
BLANK